Near Surface Disposal Facility

232-509220-REPT-004
UNRESTRICTED

Deep River, Renfrew County, Ontario

ENVIRONMENTAL IMPACT STATEMENT

Volume 1: EIS Report

Revision 0

Canadian Nuclear Laboratories

Laboratoires Nucléaires Canadiens

Prepared by:

Golder Associates

Project Number: 1547525
March 2017

Table of Contents

TABLES

FIGURES

PHOTOS

APPENDICES

This page intentionally left blank

1.0 INTRODUCTION

Canadian Nuclear Laboratories (CNL) is proposing to construct a Near Surface Disposal Facility (NSDF) for the disposal of radioactive waste at Chalk River Laboratories (CRL) – the NSDF Project. Canadian Nuclear Laboratories (CNL) is a private-sector company that is contractually responsible for the management and operation of nuclear sites, facilities and assets owned by Atomic Energy of Canada Limited (AECL); a federal Crown corporation. To support the future plans for the CRL property, CNL identified the need for a disposal facility capable of accepting radioactive waste from legacy waste management areas, current operations, and decommissioning projects at Chalk River Laboratories and its other business locations. The NSDF Project is rooted in the requirements established by Atomic Energy of Canada Limited, on behalf of the Government of Canada, to substantially reduce the risks associated with the CNL legacy wastes, liabilities, and to create the conditions for the revitalization of the CRL property. The NSDF Project will enable the site revitalization through improved environmental management of Government of Canada legacy waste liabilities and the decommissioning of outdated infrastructure at the CRL property and other business locations. The current CRL waste management practice is to store radioactive waste on-site in individual facilities in accordance with current licence conditions. To accommodate the disposal of current and future radioactive waste at the site, CNL is proposing to develop an engineered NSDF on the CRL property (Figure 1.0-1).

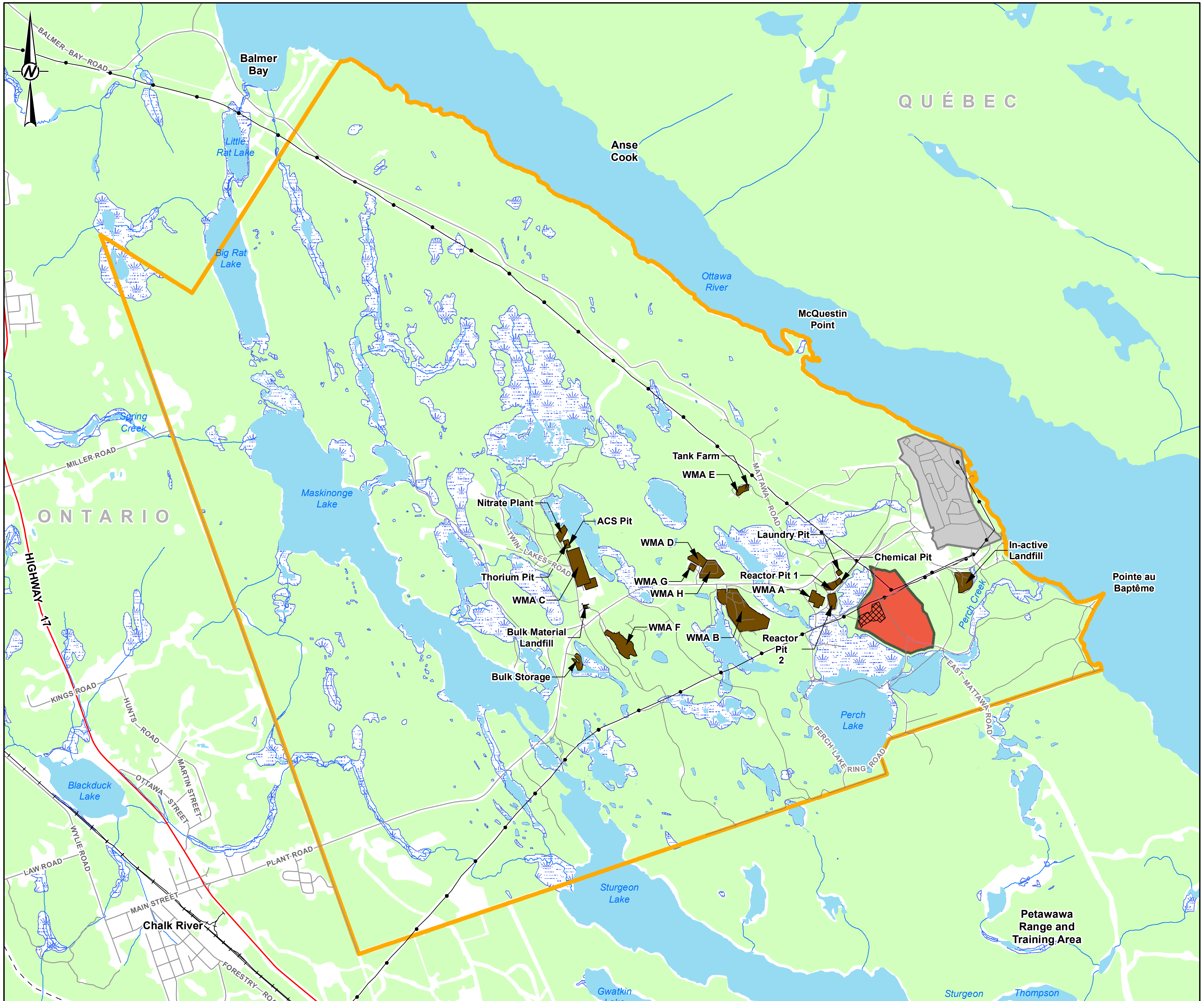
Essentially all of the waste to be emplaced in the NSDF will be low-level waste (LLW); however, the NSDF Project may also accept approximately 1% by volume of intermediate-level waste (ILW) and mixed wastes. Low-level waste is material with radionuclide content above established clearance levels and exemption quantities, but with limited amounts of long-lived activity (IAEA 2009). The ILW are wastes with higher levels of radioactivity that may require shielding for worker protection during handling, and may contain higher concentrations of longer-lived radionuclides (IAEA 2009). Mixed waste is radioactive waste that also contains hazardous substances. All waste to be disposed at the NSDF Project will be required to meet the waste acceptance criteria (WAC) established to assure operational and post-closure safety requirements.

Canadian Nuclear Laboratories (CNL) is proposing to carry out the designated NSDF Project on land that is held in the name of AECL, which is property of the Crown. As such, CNL is the proponent for the development of the NSDF Project and associated infrastructure.

A key element of the regulatory approvals process is the completion of an environmental assessment under the *Canadian Environmental Assessment Act, 2012* (CEAA 2012), the results of which are documented in this Environmental Impact Statement (EIS). The Environmental Impact Statement includes an analysis of alternatives, a process of public and Aboriginal engagement, studies of baseline conditions, and a description and assessment of project activities during the construction, operation, closure and post-closure phases of the NSDF Project.

This page left intentionally blank

232-509220-REPT-004
UNRESTRICTED



LEGEND

- HIGHWAY
- ROAD
- RAILWAY
- TRANSMISSION LINE
- NATURAL GAS PIPELINE
- RIVER/STREAM
- WATERBODY
- WETLAND
- WOODED AREA
- TREE RESEARCH PLANTATION
- NSDF PROJECT SITE
- CRL MAIN CAMPUS
- CRL PROPERTY
- WASTE MANAGEMENT AREAS (WMA)[1]

1 0 1
1:35,000 KILOMETRES

NOTE(S)
1. LIQUID DISPERSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.

REFERENCE(S)
1. BASEDATA ONTARIO MNRF 2016, CANVEC 2016, AND CNL 2016
2. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
3. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
LOCATION OF NEAR SURFACE DISPOSAL FACILITY

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	MM
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0001	0.0	1.0-1

25mm
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:

S:\Clients\Canadian_Nuclear_Laboratories\NSDF\99_PROJ\1547525_NSDF_EIS\40_PROD\0001_EIS_Section_1\1547525-0001-G-0001.mxd

This page left intentionally blank

1.1 Project Overview

The NSDF will be designed as an engineered containment mound (ECM), and built at near-surface level on the CRL property. The facility is expected to be operational for approximately 50 years and will be expanded to receive up to 1,000,000 cubic metres (m^3) of radioactive waste over its operational lifetime. The placement of the wastes in the engineered containment mound will be completed in a staged approach:

- Stage 1[1]: during which the design capacity is 525,000 m^3 of waste to accommodate wastes currently in storage and to be generated over the next 20 to 25 years, to create the conditions for the revitalization of the CRL property.
- Stage 2: during which the design capacity is expanded to 1,000,000 m^3 of waste to accommodate wastes expected to be generated following the first stage.

Stage 2 will allow for the inclusion of waste from future operations, decommissioning and remediation at CRL and off-site CNL facilities. A few percent of the waste volumes to be placed in the ECM will be from off-site sources (e.g., Whiteshell Laboratories, commercial sources such as hospitals and universities).

The main physical works related to the NSDF Project are the ECM that will contain the waste, the wastewater treatment plant (WWTP), operation support facilities and site infrastructure. The ECM will consist of ten disposal cells and include the following:

- base liner, including primary and secondary systems;
- leachate collection system;
- surface water management system;
- final cover system; and,
- environmental monitoring systems.

The base liner system includes a primary and secondary liner to contain the waste and to limit the potential release of contaminated water (i.e., leachate) to the subsurface and groundwater. The surface water management system will control clean surface water on-site, while preventing contact with contaminated areas. The final cover system (i.e., cap for the mound) will be designed to eliminate exposure due to direct contact with waste, and provide gamma radiation shielding. It will also limit the infiltration of precipitation to the waste, thereby limiting leachate generation. The environmental monitoring systems will monitor air, surface water and groundwater consistent with existing CRL licence requirements.

The WWTP will be required to treat leachate collected from the ECM and wastewater from the NSDF supporting operations. The WWTP will treat these liquids such that they meet discharge criteria prior to transfer to an approved discharge location. Operation support facilities include key installations such as a vehicle decontamination facility, weighing stations, laydown and stockpiling area, office and change room facilities, parking and security systems.

[1] The EIS refers to these as construction stages to differentiate from assessment phases, whereas the design documentation refers to these as construction phases.

Construction of site infrastructure, including a main access road to the NSDF and a perimeter road from the ECM will provide direct access for construction vehicles and maintenance activities.

Canadian Nuclear Laboratories (CNL) aims to have the NSDF ready for operations by end of March 2020. Development of the NSDF Project is planned in several phases. The construction phase, which includes site preparation, is anticipated to start in 2018 or as soon as the relevant regulatory permits and approvals are in place. The operations phase is anticipated to begin in 2020 and will end in approximately 2070 (i.e., operating site life of 50 years). Activities associated with the closure phase primarily include those activities necessary to complete the installation of final cover of the ECM, continued treatment of residual leachate, and continued environmental monitoring. Closure activities are expected to start in 2070 and continue through to 2100, after which the NSDF Project will transfer into the post-closure phase. The post-closure phase is defined by two discrete periods: Institutional Control and post-Institutional Control. The Institutional Control period includes implementation of both active and passive control throughout 2100 to 2400 (i.e., 300 years). During Institutional Control, groundwater monitoring and groundwater quality management will continue to demonstrate compliance with the safety case assumptions. Post-Institutional Control occurs after year 2400 and continues indefinitely.

1.2 Project Location

The CRL property is located in Renfrew County, Ontario on the shore of the Ottawa River. The CRL property contains several licence-listed nuclear facilities, including the National Research Universal reactor, waste management areas, and many other nuclear and non-nuclear facilities and laboratories. Two hydro lines cross the CRL property and provide electricity for CRL operations. The property has a total area of 4,000 hectares (ha) and is located approximately 200 kilometres (km) northwest of Ottawa, and within the boundaries of the Corporation of the Town of Deep River (Figure 1.2-1). The Federal Department of National Defence Garrison Petawawa borders the CRL property to the southeast, and the Village of Chalk River in the Municipality of Laurentian Hills is to the southwest. The Ottawa River forms the northeastern boundary of the property. The NSDF Project is proposed to be located entirely within the CRL property (Figure 1.0-1). The approximate geographic coordinates of the NSDF Project are 46 02’ 33” N, 77 22’ 13” W.

Nearby population centres include the Village of Chalk River (5 km west of the property) and the Town of Deep River (12 km northwest of the property). Surrounding these communities are the Townships of Rolphton, Buchanan, Wylie and McKay, which with Chalk River, form the Municipality of Laurentian Hills. The Town of Deep River has approximately 4,200 residents and the Municipality of Laurentian Hills has around 2,800. The Town of Petawawa and the Canadian Forces Base Petawawa, totalling about 16,000 residents are located 20 km southeast of CRL. The other population centre of interest in the region is Pembroke, with about 14,360 residents, 35 km southeast of the CRL property. The portion of the Pontiac Regional County Municipality in the Province of Quebec that lies north of the Ottawa River and opposite the CRL property is normally uninhabited except during the summer months, when a few cottage dwellers may be present (CNL 2015a). The closest permanent residents in the Pontiac Regional County Municipality are located 11 km southeast of CRL, in the Harrington Bay area. The closest community on the Quebec side of the Ottawa River is Sheenboro, about 15 km downstream.

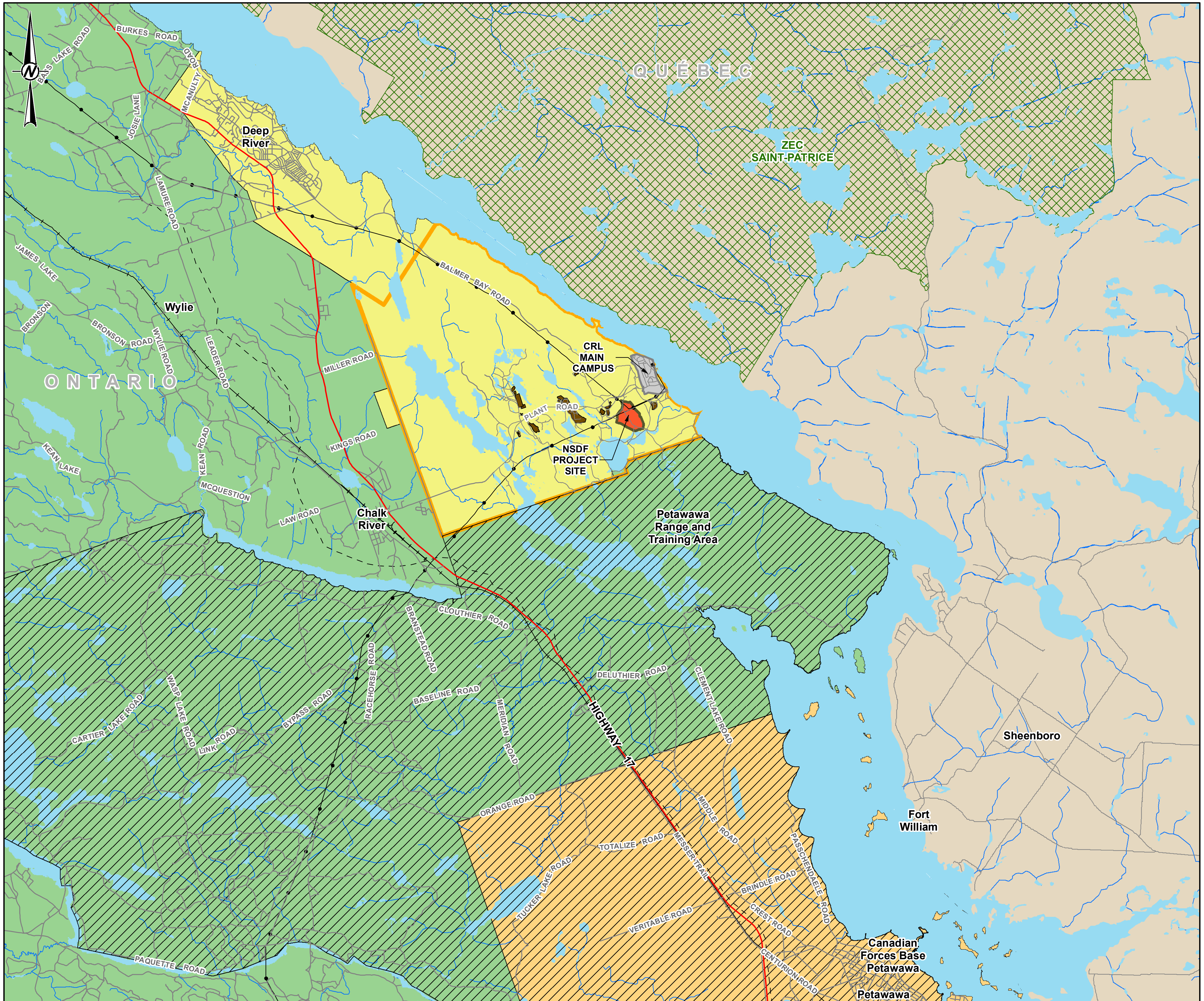
The closest First Nations community is the Algonquins of Pikwàkanagàn, located at Golden Lake, approximately 50 km southeast of the CRL property. The Algonquins of Pikwàkanagàn First Nations are part of the larger Algonquins of Ontario organization, which has reached an Agreement-In-Principle with the Governments of Ontario and Canada regarding a land claim in the Ottawa Valley, which they consider their traditional homelands. The area that is subject of the Algonquin claim in Ontario includes the National Capital Region, all of Renfrew County, and most of Algonquin Park (CNL 2016). In addition, the CRL property falls within the Métis Nation of Ontario's Ottawa River traditional harvesting territory (MNO 2004).

The Ottawa River is the dominant drainage feature in the area. The CRL property contains several small drainage basins that drain directly to the Ottawa River or to smaller lakes and streams on-site, which in turn drain to the Ottawa River. The CRL property is located in the Allumette Lake and Lac Coulonge reach of the Ottawa River, which extends approximately 90 km between La Passe and the Des Joachims Dam. The distance from the centre of the NSDF Project site to the closest point on the Ottawa River is approximately 1 km. Perch Lake is located southwest of the NSDF Project site (Figure 1.0-1).

The CRL property supports a diverse mix of upland and wetland habitats. Vegetation includes deciduous and coniferous forest and a wide variety of plant species. In the western region of the NSDF Project site, approximately 2.6 ha of land is occupied by a Petawawa Research Forest Plantation. The plantation was established in 1956 to determine frost and White Pine weevil resistance in Norway spruce. The Petawawa Research Forest has confirmed it no longer has interest in this plantation. The south and west boundaries of the NSDF Project site are adjoining the Perch Lake wetland complex (Figure 1.0-1).

Aside from the operations and activities undertaken by CNL, other land uses of the CRL property are prohibited due to restricted public access. No hunting or fishing is permitted on the CRL property and the property is not used for traditional purposes by First Nation and Métis people (AECL 2013). Land use in the region consists primarily of forestry, recreation and tourism, with limited agriculture, trapping and mining. The nearest area of considerable agriculture and dairy farming is 15 km southeast on the Quebec side of the Ottawa River and 35 km southeast on the Ontario side. The Ottawa River is an important recreational resource for swimming, sport fishing and boating; there is little commercial fishing opportunity. There are several sand beaches along both sides of the river that provide popular recreational sites. In addition, two provincial parks, Algonquin and Driftwood, are located to the west of CRL, which offer opportunities for canoeing, hiking, fishing and hunting. Winter recreational activities in the region include cross-country skiing, snowmobiling and ice-fishing.

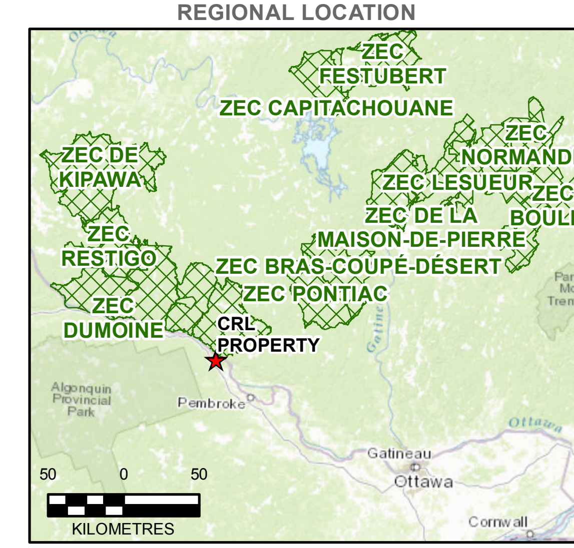
This page left intentionally blank



LEGEND

- HIGHWAY
- ROAD
- RAILWAY
- TRANSMISSION LINE
- NATURAL GAS PIPELINE
- RIVER/STREAM
- WATERBODY
- TOWN OF DEEP RIVER
- MUNICIPALITY OF LAURENTIAN HILLS
- MUNICIPALITY OF PETAWAWA
- PONTIAC REGIONAL COUNTY MUNICIPALITY
- CONTROLLED HARVESTING ZONE (ZEC)
- CFB PETAWAWA
- NSDF PROJECT SITE
- CRL MAIN CAMPUS
- CRL PROPERTY
- WASTE MANAGEMENT AREAS (WMA)[1]

REGIONAL LOCATION



2.5 0 2.5

1:100,000 KILOMETRES

NOTE(S)

1. LIQUID DISPERSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.

REFERENCE(S)

1. BASEDATA ONTARIO MNRF 2016, CANVEC 2016, QUÉBEC MRNF 2016 AND CNL 2016
2. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
3. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE

CLIENT

CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT

NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE

GENERAL LOCATION OF THE CHALK RIVER LABORATORIES PROPERTY

CONSULTANT

Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	MM
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0001	0.0	1.2-1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:

25mm

This page left intentionally blank

1.3 Proponent

Canadian Nuclear Laboratories (CNL) is the proponent for the development of the NSDF Project, on land held in the name of AECL, which is property of the Crown. The Government of Canada (i.e., the Crown) is responsible for the long term management of AECL lands including the CRL property, the proposed location of the NSDF Project. The Crown has mandated AECL to manage their radioactive waste and decommissioning responsibilities, who has contracted CNL to manage the licenced sites and nuclear activities.

1.3.1 Corporate History

Canadian Nuclear Laboratories is Canada's leading nuclear science and technology organization and a world leader in developing innovative applications from nuclear technology. Services offered through CNL include research and development, design and engineering to specialized technology, waste management and site decommissioning.

Canadian Nuclear Laboratories is committed to ensuring that Canadians and the world receive energy, health, and environmental benefits from nuclear science and technology with confidence that nuclear safety and security are assured. CNL works to deliver safety, execution and innovation, in all work activities and providing the highest performance in meeting the commitments expected of them by their regulators, customers, stakeholders and the public.

Atomic Energy of Canada Limited is a federal Crown corporation, with a core mandate to deliver on Canada's radioactive waste and decommissioning responsibilities, provide nuclear expertise to support federal responsibilities, and offer services to users of the nuclear laboratories on commercial terms. It fulfils this mandate through a long-term contractual arrangement with CNL for the management and operation of AECL's sites, facilities and assets, and the performance of AECL's waste and decommissioning responsibilities, under a Government-owned, Contractor-operated ("GoCo") model.

1.3.2 Management Structure

Canadian Nuclear Laboratories is led by an Executive Team and a Board of Directors. The President and Chief Executive Officer, along with nine vice-Presidents are responsible for different aspects of the business. An organizational chart outlining CNL's internal structure relevant to the NSDF Project is provided on Figure 1.3-1. A full listing of CNL's Board of Directors and Executive Team can be found online at www.cnl.ca. Four Vice Presidents are associated with the execution of the NSDF Project:

- The Vice President, Decommissioning and Waste Management, who has overall responsibility for the development of the NSDF Project.
- The Vice President Operations, who is the Site Licence Holder and is responsible for the operation of the facility after it is turned over to operations. The Vice President, Operations delegates the responsibility for safe operation of the NSDF to the Waste Management Area Facility Authority (illustrated as a dashed line on Figure 1.3-1).
- The Vice President, Health, Safety, Security, and Environment & Quality, who has overall responsibility for compliance programs. These include Radiation and Environmental Protection, Occupational Safety and Health, and Emergency Preparedness. The facility will be designed and operated to meet compliance program requirements.

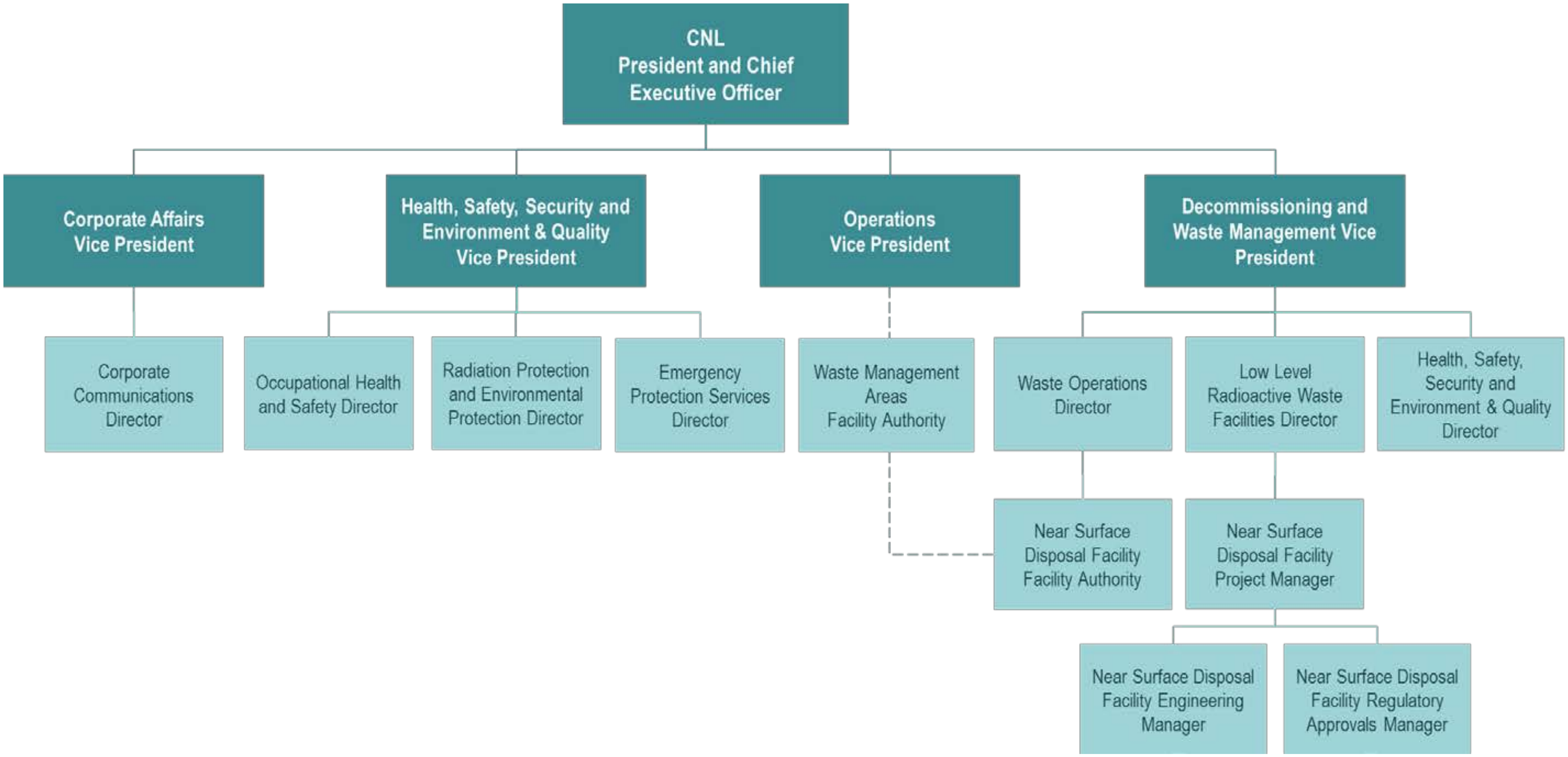


Figure 1.3-1: Organizational Chart for the Canadian Nuclear Laboratories and Management of the Near Surface Disposal Facility Project

- The Vice President, Corporate Affairs, who is accountable for the facilitation of engagement activities with stakeholders and First Nations and Métis communities to support the NSDF Project development. The Vice President, Corporate Affairs delegates the responsibility for First Nations and Métis communities and stakeholder engagement to the Director of Corporate Communications.

1.3.3 Key Contact Information

The primary contact for the purposes of the EIS for the NSDF Project is:

Mr. Pat Quinn
Director, Corporate Communications
Canadian Nuclear Laboratories
Chalk River Laboratories
286 Plant Road, Building 700
Chalk River, Ontario K0J 1J0
Telephone: 613 584 8811 Extension 43417
Email: pat.quinn@cnl.ca

1.3.4 Environmental Policy

Canadian Nuclear Laboratories (CNL) has an Environment Policy that considers the protection of the environment as an integral component of their decision-making in all phases of their business activities, including product development, project planning, project implementation, operations and decommissioning. Canadian Nuclear Laboratories (CNL) also focuses their environmental efforts on limiting nuclear legacy obligations for future generations. The Environment Policy applies to all aspects of CNL's activities and is as outlined below:

- To practice responsible environmental management.
- To be committed to pollution prevention.
- To set environmental objectives and targets to support continual improvement of their environmental performance.
- To comply with environmental laws, requirements, and recognized standards and guidelines applicable to their activities.
- To review the impacts of their activities, facilities, projects, services and products on the environment.
- To seek to develop and improve technologies to advance environmental protection and clean air solutions.
- To promote public and employee awareness of this policy and their environmental performance.

1.3.4.1 Health, Safety, Security and Environmental Programs

To demonstrate compliance with the Environment Policy (CNL 2015b) and other regulatory commitments related to health, safety and security, CNL has developed a number of programs outlining corporate expectations regarding the following activities (further detail is provided in Section 3.0):

- Corporate Security;
- Dosimetry Services;
- Emergency Preparedness;
- Environmental Protection;
- Fire Protection;
- Human Performance;
- Nuclear Criticality Safety;
- Nuclear Materials and Safeguards Management;
- Occupational Safety and Health;
- Operating Experience;
- Radiation Protection;
- Radioactive Material Transportation;
- Physical Security; and,
- Waste Management.

1.3.4.2 Environmental Plan

The Environmental Plan is prepared in support of the Environment Policy. It describes the strategic environmental objectives for CNL sites. The Environmental Plan currently includes initiatives to:

- Manage legacy radioactive waste.
- Upgrade or construct new infrastructure related to current operations.
- Manage and monitor emissions.
- Implement “Green Initiatives” to improve waste management, energy and vehicle usage.

1.4 Regulatory Framework

1.4.1 Federal Review Process

The federal environmental assessment requirements are detailed within CEAA 2012. Under Section 8 of CEAA 2012, a Project Description is required to initiate the screening process through which the CNSC will determine if a federal environmental assessment is required for all designated projects. Designated projects are defined under the *Regulations Designating Physical Activities* for CEAA 2012. The Regulations Designating Physical Activities identify the CNSC as the Responsible Authority for projects that are regulated under the *Nuclear Safety Control Act*. As such, the CNSC is responsible for the conduct of the environmental assessment and ensuring that the requirements of CEAA 2012 are met. Following submission of the 2016 Project Description document (CNL 2016), the CNSC issued a Notice of Commencement and determined that the NSDF Project requires a federal environmental assessment pursuant to CEAA 2012.

Federal permits, licences, and authorizations that may be required for the NSDF Project are listed below:

- Environment Canada:
  - A permit from Environment Canada will be required under the *Species at Risk Act* (s73).

- Petroleum storage tank permit(s) may be required, depending on the size of fuel tanks installed on the site.

- Fisheries and Oceans Canada: a project review may be required, depending on the design of any water discharge or intake.

The NSDF Project is located on Federal lands and is regulated under the CNSC, therefore, it is anticipated that provincial permits, licences or other authorizations are not required.

1.4.2 Relevant Standards, Codes and Guidelines

It is critical that the environmental assessment be conducted in accordance with relevant standards and codes, while also taking into consideration appropriate guidelines. The environmental assessment is completed in a manner consistent with direction in:

- *Canadian Environmental Assessment Act, 2012* (CEAA 2012). SC 2012, c 19, s 52;
- Operational Policy Statement: Assessing Cumulative Environmental Effects under the *Canadian Environmental Assessment Act, 2012* (the Agency 2015a);
- Operational Policy Statement: Addressing the "Purpose of" and "Alternative Means" under the *Canadian Environmental Assessment Act, 2012* (the Agency 2015b);
- Operational Policy Statement: Determining Whether a Designated Project is Likely to Cause Significant Adverse Environmental Effects under the *Canadian Environmental Assessment Act, 2012* (the Agency 2015c);
- Reference Guide Considering Aboriginal Traditional Knowledge in Environmental Assessments Conducted Under the *Canadian Environmental Assessment Act, 2012* (the Agency 2015d);
- Technical Guidance for Assessing Physical and Cultural Heritage or any Structure, Site or Thing that is of Historical, Archeological, Paleontological or Architectural Significance under the *Canadian Environmental Assessment Act, 2012* (the Agency 2015e);
- Draft Technical Guidance for Assessing Cumulative Environmental Effects under the *Canadian Environmental Assessment Act, 2012* (the Agency 2014);
- Generic Guidelines for the Preparation of an Environmental Impact Statement pursuant to the *Canadian Environmental Assessment Act, 2012* (CNSC 2016a)
- REGDOC-3.2.2 Public and Aboriginal Engagement: Aboriginal Engagement (CNSC 2016b)
- REGDOC-2.9.1 Environmental Protection: Environmental Principles, Assessments and Protection Measures (CNSC 2016c);
- Regulatory Guide G-320: Assessing the Long-term Safety of Radioactive Waste Management (CNSC 2006);
- CSA N286-12: Management System Requirements for Nuclear Facilities (CSA Group 2012a); and,
- CSA N288.6-12: Environmental Risk Assessment at Class 1 nuclear facilities and uranium mines and mills. (CSA Group 2012b).

Discipline-specific standards, codes and guidelines used in the assessment of effects are identified as appropriate within each discipline section (Sections 5.2 to 5.10).

To demonstrate compliance with the Generic Guidelines for the Preparation of an Environmental Impact Statement pursuant to the *Canadian Environmental Assessment Act, 2012* (CNSC 2016a), REGDOC-2.9.1 Environmental Protection: Environmental Principles, Assessments and Protection Measures (CNSC 2016c), and facilitate access to information within the EIS document, a concordance table (or cross-referencing table) has been prepared (Appendix 1.0-1) that lists the requirements detailed in the Guidelines and REGDOC 2.9.1 and the location for the corresponding information provided within the EIS.

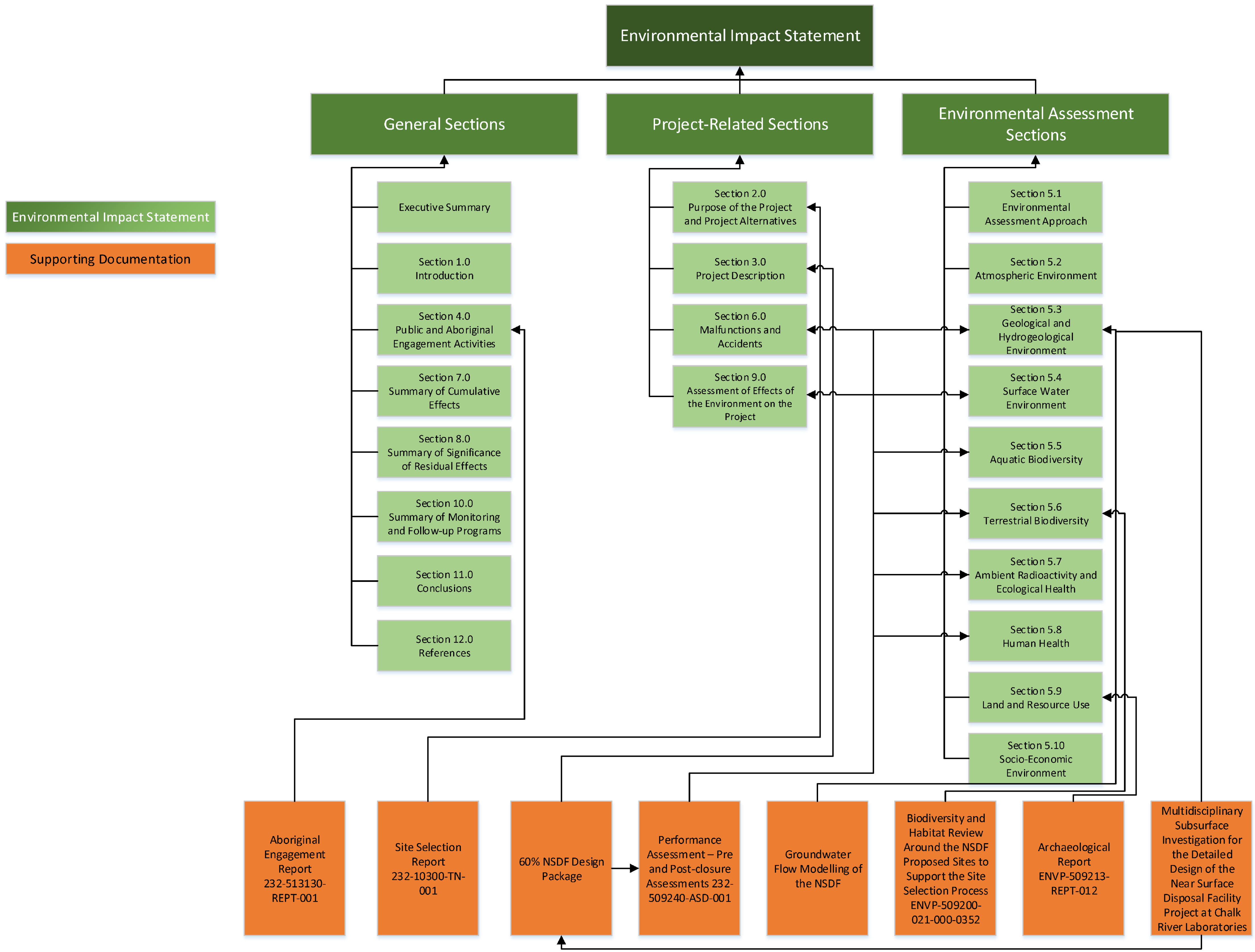
1.5 Structure of the Document

This document represents CNL's EIS for the NSDF Project. It has been prepared following the Generic Guidelines for the Preparation of an Environmental Impact Statement pursuant to the *Canadian Environmental Assessment Act, 2012* (CNSC 2016a). This EIS is organized into the following sections described below and shown on Figure 1.5-1 (only those documents shown in green on Figure 1.5-1 will be submitted as part of the EIS; the remaining documents are technical support references):

- **Executive Summary –** contains a description of all key components of the NSDF Project and related activities, a summary of all engagement activities, an overview of the results of the environmental assessment, and a summary of the conclusions on the residual environmental effects of the NSDF Project after considering mitigation and the significance of those residual effects.
- **Section 1.0 Introduction –** includes an overview of the NSDF Project, provides an introduction to CNL, outlines the regulatory framework the NSDF Project will follow, and outlines the organization of the document.
- **Section 2.0 Purpose of the NSDF Project and Alternative Means for Carrying out the NSDF Project –** identifies the objectives of the NSDF Project, the problems or opportunities that the NSDF Project is intended to satisfy, and presents the rationale for proceeding with the development. This section also considers the effects of alternative means of carrying out the NSDF Project, identifies the economically and technically feasible alternatives, and includes environmental and social considerations that were evaluated as means of implementing the NSDF Project.
- **Section 3.0 Project Description –**provides a description of all phases of the NSDF Project in sufficient detail to allow CNL to predict potential adverse environmental, economic, social, and health effects and to address concerns from interested parties; timeline for all phases of the NSDF Project is provided, as well as a discussion of components and activities, including infrastructure that will be developed as part of the NSDF Project.
- **Section 4.0 Engagement –** summarizes CNL's engagement activities, including documentation of meetings, discussion topics and outcomes, and relevant agreements that were developed.

- **Section 5.0 Environmental Effects –** outlines the environmental assessment approach, selection of valued components (VC), discipline-specific definition of assessment boundaries, describes the NSDF Project setting and baseline characterization, and presents the results of the environmental assessment and determination of significance of effects on the environmental, economic, social, heritage and health effects of the NSDF Project. Section 5.0 Environmental Effects comprises the following subsections:
    - Section 5.1 Environmental Assessment Approach;
    - Section 5.2 Atmospheric Environment;
    - Section 5.3 Geological and Hydrogeological Environment;
    - Section 5.4 Surface Water Environment;
    - Section 5.5 Aquatic Biodiversity;
    - Section 5.6 Terrestrial Biodiversity;
    - Section 5.7 Ambient Radioactivity and Ecological Health;
    - Section 5.8 Human Health;
    - Section 5.9 Land and Resource Use; and,
    - Section 5.10 Socio-economic Environment.
- **Section 6.0 Malfunctions and Accidents –** presents a description of potential credible malfunctions and accidents associated with the NSDF Project, the conditions under which they could occur, proposed mitigations and contingency plans.
- **Section 7.0 Summary of Cumulative Effects –** contains a summary of residual cumulative environmental, economic, social, and health effects predicted to occur as a result of the NSDF Project that cannot be avoided or mitigated through the re-design or relocation of the NSDF Project or through commitments made by CNL.
- **Section 8.0 Summary of Significance of Residual Effects –** contains a summary of significance of residual environmental, economic, social, and health effects predicted to occur as a result of the NSDF Project that cannot be avoided or mitigated through the re-design or relocation of the NSDF Project or through commitments made by CNL, and will present the conclusion of the evaluation of significance for residual effects predicted to occur to VCs for Project effects and cumulative effects.
- **Section 9.0 Assessment of Effects of the Environment on the NSDF Project –** contains the assessment of effects of the environment on the NSDF Project including the likelihood and severity of the changes or effects, and mitigation planned to avoid or limit the changes or effects. The assessment also includes consideration of effects from climate change.
- **Section 10.0 Summary of Monitoring and Follow-up Programs –** presents the reporting structure and timelines for the various management plans, continuing or follow-up monitoring plans and commitments made for the NSDF Project.
- **Section 11.0 Conclusions – i**ncludes a summary of the findings of the effects assessments, the significance of the NSDF Project and the residual effects predicted to occur because of the NSDF Project and other reasonably foreseeable developments, and provides an overall conclusion for the EIS.
- **Section 12.0 References –** includes the references cited throughout the EIS.

This page left intentionally blank



CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
ENVIRONMENTAL IMPACT STATEMENT DOCUMENT STRUCTURE

CONSULTANT

Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	MM
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0001	0.0	1.5-1

This page intentionally left blank

2.0 PURPOSE OF THE PROJECT AND PROJECT ALTERNATIVES

2.1 Introduction

Canadian Nuclear Laboratories (CNL) is proposing the development of a facility for the disposal of up to 1,000,000 cubic metres (m^3) of solid radioactive waste from legacy waste management areas, current operations, and future environmental remediation and decommissioning projects at Chalk River Laboratories (CRL) property and its other business locations. The Near Surface Disposal Facility (NSDF) Project will provide a safe, permanent solution at the CRL property for the disposal of low-level waste (LLW) and other acceptable waste streams and replace the current CNL practice of placing waste in interim storage. The intent of this section is to provide an overview of the existing, planned and anticipated waste disposition routes of CNL radioactive wastes, describe the purpose of the project as it relates to this overall waste disposal strategy, and to present alternative means of carrying out the proposed NSDF Project.

2.2 CNL Integrated Waste Strategy

Canadian Nuclear Laboratories has developed an Integrated Waste Strategy (IWS) which concisely details “cradle to grave” pathways for all CNL waste streams, from generation to final disposition. The IWS is based on CNL’s waste inventory and forecast data and founded on the fundamental principles of waste avoidance, minimization and re-use. It enables the assessment of the quantities and types of waste across the spectrum of waste that CNL manages, (e.g., from clearable waste to used fuel). The NSDF will provide the main disposition route for waste arising from near-term decommissioning and demolition and legacy waste clean-up activities. The LLW debris and soils that will arise from these activities represent more than 80 percent (%) of the total radioactive waste volume forecast to be generated through 2045.

This section provides a brief overview of the existing and anticipated waste disposition routes of CNL radioactive wastes, of which the development of NSDF Project is a key part. Table 2.2-1 summarizes the planned disposition route for each type of radioactive waste. Figure 2.2-1 graphically demonstrates the disposition path for inactive (clean) waste, as well as that for radioactive and hazardous waste generated at CNL.

Table 2.2-1: Solid Radioactive Waste Classification and Disposition Plan

Waste Class	Description of Waste[a]	Planned Disposition
High Level Waste (Fuel)	High-level waste (HLW) includes used nuclear fuel and other wastes (e.g., fuel reprocessing wastes) that have been declared as radioactive waste that generate significant heat via radioactive decay. Used nuclear fuel is associated with penetrating radiation and contains significant quantities of long-lived radionuclides.	■ Repatriation for Highly Enriched Uranium material to the United States, and/or ■ National Deep Geological Repository (proponent is Nuclear Waste Management Organization [NWMO])
Intermediate Level Waste	Intermediate–level waste (ILW) typically exhibits levels of penetrating radiation sufficient to require shielding during handling and interim storage and contains significant quantities of long-lived radionuclides (IAEA 2009).	■ Interim storage until a final disposal facility is available ■ Limited quantities of ILW may be suitable for disposal in the NSDF Project (see Section 2.2.2.1) ■ Whiteshell Laboratories (WL) Whiteshell Reactor (WR-1) and Nuclear Power Demonstration (NPD) – In-Situ entombment
Low Level Waste	Low-level waste (LLW) contains material with radionuclide content above established clearance levels and exemption quantities, but generally has limited amounts of long-lived activity. LLW requires isolation and containment for up to a few hundred years.	■ NSDF ■ In-Situ (WL WR-1 and NPD) ■ Sewage sludge in the CRL Bulk Material Landfill ■ Port Hope Long-term Waste Management Facility[a] ■ Port Granby Long-term Waste Management Facility[a]
Hazardous Waste	Materials that are potentially hazardous to human health and/or the environment due to their nature and quantity and that require special handling and storage techniques.	■ Licensed commercial disposal facility
Mixed Waste	Radioactive waste that also contains hazardous substances.	■ Licensed commercial disposal facility ■ NSDF
Clean (Inactive) Waste	Non-hazardous material that is declared to be non-radioactive by its history, location and use, or non-hazardous material that has been determined to meet regulatory requirements for unconditional clearance by means of suitable radiological monitoring.	■ Reuse and recycling ■ On-site inactive landfill ■ Off-site public landfills

(a) The Port Hope and Port Granby Long-term Waste Management Facilities are facilities for wastes within the Municipality of Port Hope, Ontario and Municipality of Clarington, Ontario, respectively.

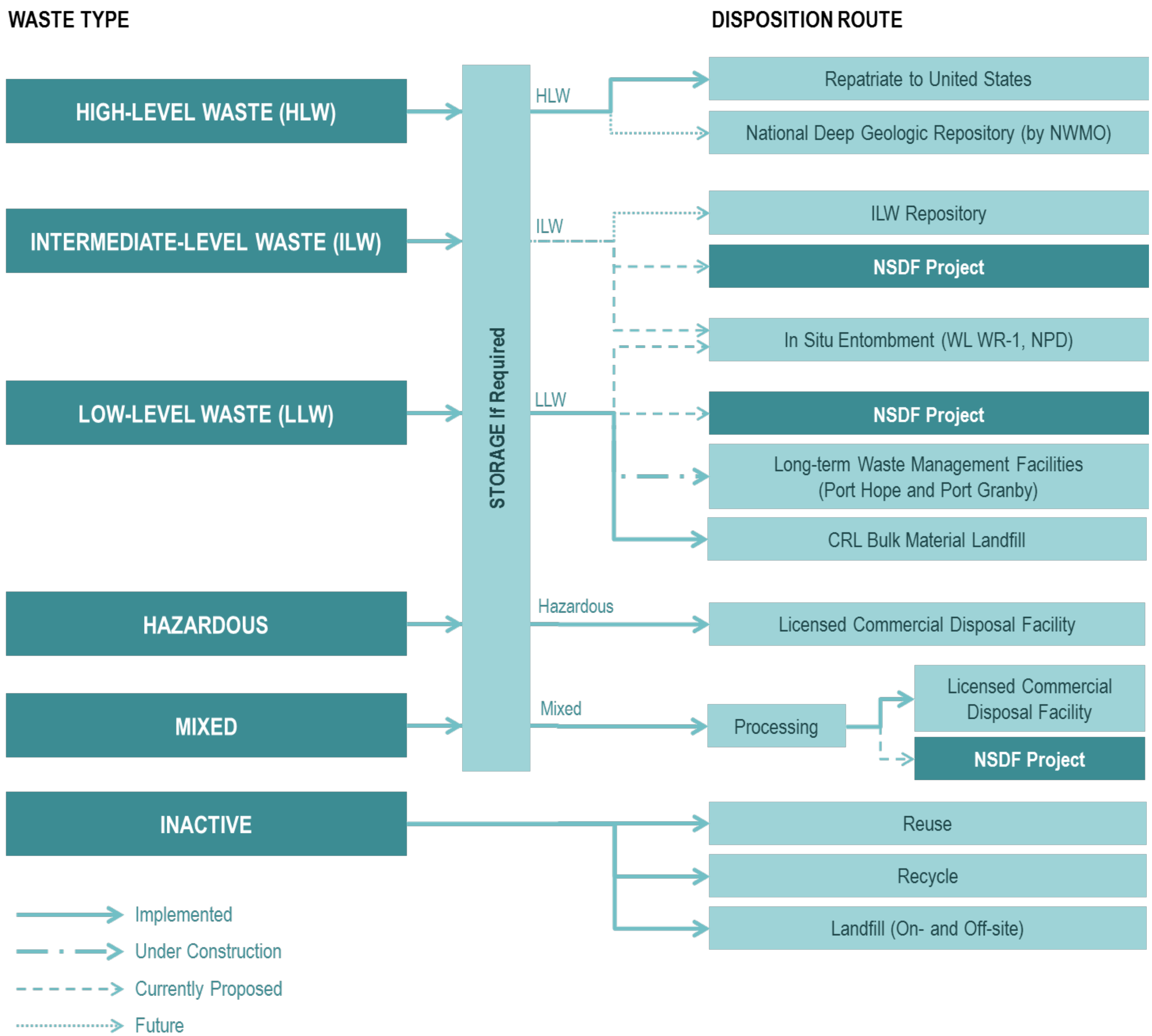


Figure 2.2-1: Overview of Canadian Nuclear Laboratories Integrated Waste Strategy

As shown in Table 2.2-1 and on Figure 2.2-1, the NSDF provides a disposal solution for low-level waste, a very small amount of intermediate-level waste (ILW; estimated to be approximately 1% by volume), and mixed wastes that meet the waste acceptance criteria (WAC). Each of the above waste streams are discussed further below.

Overall, LLW comprises the vast majority of the radioactive waste in storage at the CNL sites, approximately 5% is ILW, and less than 1% is high-level waste (HLW). A breakdown of the waste classes in storage in 2015 and predicted to be in storage/disposal in 2100, by total volume, is presented in Figure 2.2-2.

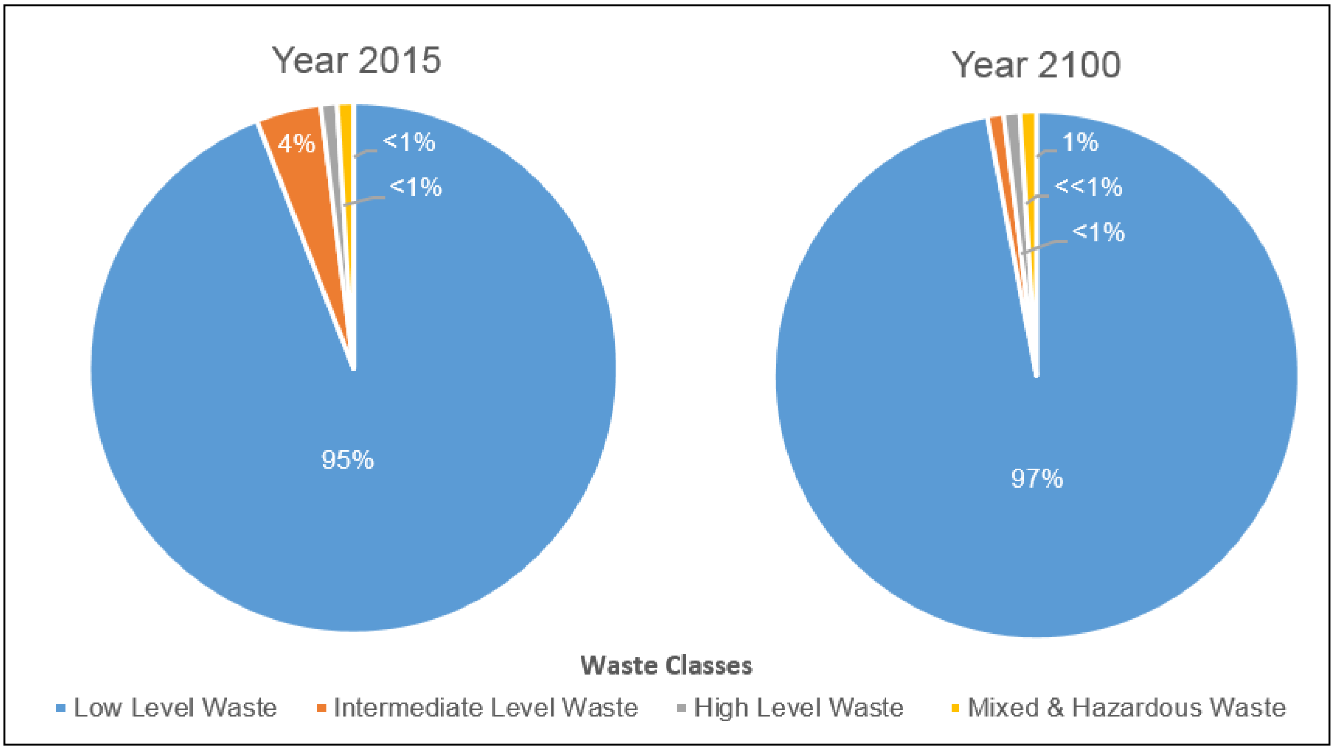


Figure 2.2-2: Canadian Nuclear Laboratories Waste Classes in Storage by Volume in 2015 and Predicted in 2100

2.2.1 High Level Waste (Used Fuel)

The CNL's used fuel that is eligible for repatriation to the United States (U.S.) under the Global Threat Reduction Initiative is being returned to the U.S. The remainder of the fuel will be sent for final disposition to a national repository designed for used fuel. The solution is currently being developed by the Nuclear Waste Management Organization (NWMO) as part of their Adaptive Phased Management plan (NWMO 2016).

2.2.2 Intermediate Level Waste & Low Level Waste

Historically, ILW and LLW have been stored on CNL sites as Low and Intermediate Level Waste (L&ILW) and segregated based on handling and storage requirements. To facilitate storage and handling, ILW and LLW are segregated to the extent practicable. At Whiteshell Laboratories (WL), and the Douglas Point and Gentilly-1 prototype reactor sites, these wastes will be segregated, packaged to meet transport requirements, and shipped to CRL for either disposal at the NSDF or placement in long-term storage pending availability of the ILW Repository (Section 2.2.2.1). The Nuclear Power Demonstration (NPD) and the Whiteshell reactors will be entombed in-situ. In the event that historic waste is identified in the Port Hope area after the closure of the two long-term waste management facilities, it will be sent to CRL for placement in the NSDF, provided it meets the WAC.

Under the IWS, the following facilities are planned or anticipated by CNL in order to support the disposal of LLW and ILW.

2.2.2.1 Near Surface Disposal Facility

The NSDF comprises an engineered containment mound (ECM), Waste Water Treatment Plant (WWTP), supporting facilities for NSDF operations, and various site infrastructure. Radioactive waste will be emplaced in the ECM and as necessary, treated in advance of shipment to the NSDF. The NSDF will accept LLW, ILW (less than 1% by volume), and other wastes that meet the WAC. The anticipated wastes that will be disposed in the ECM are further described in Section 3.2.

2.2.2.2 Intermediate Level Waste Repository

The IWS recognizes the need for a disposal solution for ILW. The feasibility of locating an ILW repository deep underground within bedrock at CRL has been assessed and it was determined that CRL bedrock is suitable for such a facility. To determine the best way forward, further options and locations need to be identified and studied, and national discussions held. Treatment of ILW may be required to meet the WAC for the future repository.

2.2.2.3 CRL Bulk Material Landfill

Sewage sludge is generated at the CRL Sanitary Sewage Treatment Plant and considered to be very low level waste (VLLW). For the foreseeable future, the sludge will continue to be placed in the CRL Bulk Material Landfill which is an engineered mound with leachate collection system (CNSC 2010).

2.2.3 Hazardous Waste

Small quantities of hazardous waste (e.g., lead, polychlorinated bi-phenyls [PCBs]) are generated at CNL sites. Hazardous waste will continue to be sent to an off-site licensed waste management service for processing and/or disposal.

2.2.4 Mixed Waste

Mixed waste is hazardous waste that is radiologically contaminated. It is generally dispositioned as it is generated and will continue to be sent to a commercial processor for treatment unless or until an appropriate local (CRL) treatment process is developed. The commercial processor returns the radioactive portion of the material to CRL, where it is stored until disposal as per the radioactive classification of the material.

Mixed waste may be accepted for disposal in the NSDF provided that it meets the intent of land disposal and leachate requirements specified in the Ontario *Environmental Protection Act*, Regulation 347 General Waste Management. Where required, mixed waste must be processed in advance of placement in the ECM.

2.2.5 Clean (Inactive) Waste

Clean (inactive) waste is dispositioned as it is generated. Clean waste suitable for reuse or recycling (e.g., paper, cardboard, plastics, metal and compostable waste) is sent to a commercial operator for processing. Concrete at CRL that has been confirmed as clean is processed and reused on site for roads and backfill. For CRL and WL, the remainder of the waste goes to the on-site in-active landfill or off-site municipal landfills. At the prototype reactor sites, suitable clean waste will be sent to a commercial processor for reuse or recycling, with the remaining waste sent to local conventional municipal landfills.

2.3 Purpose of the Project

Chalk River Laboratories is a nuclear research establishment with a number of research reactors, fuel fabrication areas, and other associated facilities. Radioactive waste produced from reactor operations and associated facilities has been, and continues to be, stored at the site's waste management areas (WMAs). In addition to this, waste is also being produced in large volumes from both decommissioning projects and remediation of contaminated lands at the CRL site. The NSDF Project will enable CNL to move from its current practice of interim waste storage and to direct waste disposal.

The purpose and urgency of the NSDF Project is rooted in the requirements established by Atomic Energy of Canada Limited (AECL), on behalf of the Government of Canada, to substantially reduce the risks associated with the CNL legacy wastes (see Table 2.2-1), liabilities and the cost of laboratory operations to taxpayers in the 10-year period 2016 to 2025, and to create the conditions for the revitalization of the CRL property. To respond to these requirements, CNL intends to reduce its radioactive waste stores, to decommission more than 100 buildings and structures that are not needed for future CNL missions, and to remediate various WMAs at the CRL property. Candiand Nuclear Laboratories will also close the WL and the NPD prototype reactor site and ship the waste that is not disposed in situ with the reactors to CRL. Canadian Nuclear Laboratories will continue to accept waste on a commercial basis (e.g., medical waste from hospitals). All of the waste from the aforementioned activities is intended to be disposed in the ECM to be established under the NSDF Project.

Canadian Nuclear Laboratories aims to have the NSDF operational and ready to accept waste by March 2020 and is expected to be operational for approximately 50 years. The ECM will be sized to hold 1,000,000 m^3 of radioactive waste and other wastes that meet the WAC which are expected to be generated through 2070 (further detailed in Section 3.2). The waste to be disposed in the NSDF includes the following:

- waste now in storage that has resulted from legacy CNL operational and decommissioning activities and past commercial activities;
- waste to be generated from the ongoing decommissioning of existing CRL buildings and structures and the remediation of contaminated lands;
- waste generated from the decommissioning of WL and prototype reactor sites that is not disposed in situ; and,
- future waste arising from continuing CNL operations, commercial activities, the decommissioning of buildings and structures that have not yet been built, and the remediation of soils from the CRL property.

2.4 Project Design Principles

The following principles and requirements are essential elements in the design of the preferred means of developing a disposal facility. The evaluation criteria presented in Section 2.5.1, namely technical feasibility, economic feasibility, and the likely environmental effects, are used to provide a comparison between the alternatives. Nevertheless, the alternative selected as the preferred or most favourable means of developing a disposal facility must meet the design principles and requirements discussed below.

2.4.1 CNL Design Principles

The safety principles applied to the design and operation of the preferred disposal facility to confirm that safety functions and objectives can be met include:

- Defence-in-depth principle;
- As Low As Reasonably Achievable principle (ALARA); and,
- Nuclear Safety Culture.

These principles are each described further in the following sections.

2.4.1.1 Defence-in-Depth Principle

The key aspects of defence-in-depth are layering of defensive principles by providing multiple layers of protection against abnormal events. When defence-in-depth is applied for all activities during the life cycle of the NSDF Project, it provides protection against a wide range of events (e.g., Anticipated Operational Occurrences) accident conditions, equipment failure or human error within the facility) and from events that originate outside the facility. Defense-in-depth consists of two components: 1) equipment and administrative features that provide preventative or mitigation to a degree proportional to the hazard potential; and 2) integrated safety management programs that control operations. Section 6.0 provides an analysis of potential accidents and malfunctions identified for the NSDF.

The application of the defence-in-depth concept to abnormal events provides that no single human or equipment failure would result in an unacceptable hazard to the workers in the facility, the public and the environment. This strategy is centred on several barriers of protection with ascending levels of importance: accommodation, mitigation and prevention. The level of application corresponds to the level of risk posed by the postulated event. To effectively control a hazard, the same basic approach has been taken using the following hierarchy of hazard control principles (CNL 2016):

- Elimination of the Hazard;
- Reduce/Replace the Hazard;
- Isolate the Hazard;
- Control the Hazard;
- Personnel Protective Equipment;
- Policies and Procedures; and,
- Documents.

Of these seven principles, the most effective is to eliminate the hazard, and wherever possible this will be the preferred or most favorable method of hazard control for the NSDF. When a hazard cannot be eliminated, then the remaining principles are implemented to various degrees to provide a significant level of defence-in-depth.

The defence-in-depth strategy is used to compensate for potential mechanical and human failure and unexpected occurrences. A series of barriers will prevent, reduce, or slow down releases of radioactivity to the environment. For human errors, prevention is achieved by a combination of process design and administrative controls (e.g., training and procedures) resulting from human factors engineering studies, as well as by establishment of a strong safety culture.

2.4.1.2 As Low As Reasonably Achievable Principle

The ALARA principle is that the residual risk associated with a particular design feature or operational procedure shall be as low as reasonably achievable. This principle is applicable to justifying risks from radiological hazards during routine operation and takes economic factors into consideration. The CNL's ALARA program will be followed and the essential elements include:

- demonstrated management commitment to the ALARA principle;
- implementation of ALARA through design, organization and management, selection and training of personnel, oversight of the Radiation Protection program, resources, and documentation;
- establishment of nuclear safety culture;
- planning and control of non-routine work;
- application of task-specific dose and dose-rate radiological control hold points; and,
- performance of regular operational reviews.

In addition to CNL's ALARA program, the Canadian Nuclear Safety Commission (CNSC) regulatory guide to the ALARA principle (CNSC 2004a) is also taken into consideration in the design of the NSDF. This document outlines approaches to achieving ALARA through the management control over work practices, qualification and training for personnel, control of occupational and public exposure to radiation, and planning for unusual situations.

The ALARA principle for the NSDF design will be achieved by implementing zoning and access control measures; maintaining adequate shielding for structures and the limited number of waste packages with high radiation fields (see Section 3.2 for details); providing process equipment segregation; establishing radiation alarms; continuous monitoring; and through operator training and approved procedures. Further reduction in operating staff doses is achieved by limiting releases through periodic inspection and preventive maintenance of equipment.

Protective measures against the hazards of ionizing radiation will be considered to be optimized when further reductions in radiation doses are outweighed by the additional efforts and costs required for their implementation. This principle applies throughout the life cycle of the NSDF Project, from design to decommissioning, and is a particularly important consideration when developing the operational procedures.

2.4.1.3 Nuclear Safety Culture

Canadian Nuclear Laboratories has adopted the Institute of Nuclear Power Operations' (INPO) nuclear safety culture definition (2004): "*Nuclear safety culture is defined as the core values and behaviors resulting from a collective commitment by leaders and individuals to emphasize safety over competing goals to ensure protection of people and the environment.*"

The following principles and traits are well recognized to contribute to a healthy nuclear safety culture:

- Personal Accountability: All individuals take personal responsibility for safety.
- Questioning Attitude: Individuals avoid complacency and continuously challenge existing conditions and activities in order to identify discrepancies that might result in error or inappropriate action.
- Effective Safety Communication: Communications maintain a focus on safety.
- Leadership Safety Values and Actions: Leaders demonstrate a commitment to safety in their decisions and behaviors.
- Decision-making: Decisions that support or affect nuclear safety are systematic, rigorous and thorough.
- Respectful Work Environment: Trust and respect permeate the organization.
- Continuous Learning: Opportunities to learn about ways to ensure safety are sought out and implemented.
- Problem Identification and Resolution: Issues potentially impacting safety are promptly identified, fully evaluated, and promptly addressed and corrected commensurate with their consequence.
- Environment for Raising Concerns: A safety-conscious work environment is maintained where personnel feel free to raise safety concerns without fear of retaliation, intimidation, harassment, or discrimination.
- Work Processes: The process of planning and controlling work activities is implemented so that safety is maintained.

The CNSC is also in the process of developing *REGDOC 2.1.2 Safety Culture for Nuclear Licensees*. This document will provide further clarification on the definition of safety culture and will highlight general safety culture requirements that apply to all licensees. Specifically, the document is expected to describe the suggested criteria for licensees to: self-assess, establish corrective action plans, and report on safety culture.

2.4.2 Design Principles from External Sources

In addition to CNL design principles, the design and operation of the NSDF will also use Canadian and international best practices and safety fundamentals, including those from the International Atomic Energy Agency (IAEA) and the CNSC.

2.4.2.1 International Atomic Energy Agency

The safety principles to be applied in all activities for radioactive waste management are set out in the IAEA Safety Fundamentals. The IAEA's Fundamental Safety Principles (IAEA 2006) outline and describe ten safety principles in terms of radiation protection in design:

1) Responsibility for Safety;
2) Role of Government;
3) Leadership and Management for Safety;
4) Justification of Facilities and Activities;
5) Optimization of Protection;
6) Limitation of Risks to Individuals;
7) Protection of Present and Future Generations;
8) Prevention of Accidents;
9) Emergency Preparedness and Response; and,
10) Protective Actions to Reduce Existing or Unregulated Radiation Risks.

The IAEA has published a specific safety guide for *Disposal of Radioactive Waste*, Specific Safety Requirements (SSR) No. 5 (IAEA 2011). The objective of SSR-5 is to set out the safety objective and criteria for the disposal of all types of radioactive waste and to establish, on the basis of the IAEA's Fundamental Safety Principles, the requirements that must be satisfied in the disposal of radioactive waste (IAEA 2011).

The IAEA has also published a specific safety guide for *Near Surface Disposal Facilities for Radioactive Waste* Specific Safety Guide SSG-29 (IAEA 2014). This document gives detailed guidance on the following, relating to design:

- containment;
- isolation;
- multiple safety functions;
- passive safety; and,
- surveillance and control of passive safety features.

The SSG-29 IAEA document provides guidance on the design and safety case development for the NSDF. Specifically, this document was used to guide the design of various activities of the NSDF, including WAC, site preparation, construction, operations, post-closure, institutional control, development of monitoring programs, and site security.

2.4.2.2 Canadian Nuclear Safety Commission

The CNSC has published the following two documents, including a regulatory guide and policy guide, which describe the CNSC's licensing philosophy, and licensing requirements related to radioactive waste management. These two documents are:

- G-320 – Assessing the Long-Term Safety of Radioactive Waste Management (CNSC 2006); and,
- P-290 – Managing Radioactive Waste (CNSC 2004b).

The purpose of the G-320 guidance document is to assist applicants for new licences and for licence renewals in assessing the long-term safety of radioactive waste management. Its scope includes:

- long term care and maintenance considerations;
- setting post-decommissioning objectives;
- establishing assessment criteria;
- assessment strategies and level of detail;
- selecting time frames and defining assessment scenarios;
- identifying receptors and critical groups; and,
- interpretation of assessment results.

The P-290 policy document describes the philosophy that underlies the CNSC's approach to regulating the management of radioactive waste and the principles that are taken into account when making regulatory decisions on waste management. Canadian Nuclear Laboratories considered these CNSC's guidance documents in developing the design and safety case for the NSDF.

In addition to the above published documents, the CNSC is currently accepting comments on a discussion paper, Radioactive Waste Management and Decommissioning (DIS-16-03), which identifies opportunities for improvement in the following areas:

- definition of waste types;
- requiring "reduce, reuse, and recycle";
- record keeping;
- licensing of waste disposal facilities, waste management facilities, and waste storage facilities;
- waste management program requirements;
- regulating remediation; and,
- release from licensing post decommissioning or remediation.

Canadian Nuclear Laboratories will continue to meet and adapt to new CNSC regulations.

2.5 Alternative Means for Carrying out the Project

The *Canadian Environmental Assessment Act, 2012* (CEAA 2012), requires that federal environmental assessments evaluate alternative means of carrying out the project that are technically and economically feasible and the environmental effects of any such alternative means. The Canadian Environmental Assessment Agency (the Agency) identifies in their Operational Policy Statement *Addressing Purpose of and Alternative Means under the Canadian Environmental Assessment Act, 2012* the overall approach for considering the "alternative means" of carrying out a project (the Agency 2015). "Alternative means" is defined as the "various technical and economically feasible ways under consideration by the proponent that would allow a designated project to be carried out". In addition, environmental effects of each alternative means are also considered including biophysical, socio-economic, and public and worker health & safety. Canadian Nuclear Safety Commission *REGDOC 2.9.1 Environmental Principles, Assessments and Protection Measures* also requires that an assessment under CEAA 2012 considers the different alternative means for carrying out the project.

The purpose of this section is to present the alternative means of developing a disposal facility for the long-term management of 1,000,000 m^3 of radioactive waste and other acceptable waste streams. The consideration of alternatives is presented for each category in three steps:

- identification of technical and economically feasible alternative means;
- identification of effects on valued components; and,
- application of criteria and completion of a comparative evaluation to identify the preferred option.

Each alternative is assessed and the most preferable option is selected after a systematic consideration of technical feasibility, economic feasibility, and environmental effects. Public engagement is a key aspect of the decision-making process. A summary of the alternative means assessment was made available to the public at open houses and input received (see Section 4.0) was taken into consideration for the final NSDF design.

The alternative means considered in the Environmental Impact Statement (EIS) are grouped into five categories, as presented in Table 2.5-1. These alternatives were evaluated in the context of the NSDF design principles (described in Section 2.4) for the development of a permanent solution for the disposal of radioactive waste and other acceptable waste streams.

Table 2.5-1: Alternative Means Evaluated for the NSDF Project

Aspect of the Disposal Facility	Alternatives Considered in the EIS
Facility Type (Near Surface vs. Deep Underground)	■ Near Surface Disposal Facility ■ Geological Waste Management Facility (GWMF)
Facility Design of Near Surface Options	■ Engineered Containment Mound (ECM) ■ Above-ground Concrete Vault
Facility Location	■ On-site (at CRL) ■ Off-site (Whiteshell Laboratories or Nuclear Power Demonstration site)
Site Selection	■ East Mattawa Road Site (at CRL) ■ Alternate Site (at CRL)

Table 2.5-1: Alternative Means Evaluated for the NSDF Project

Aspect of the Disposal Facility	Alternatives Considered in the EIS
Leachate Treatment System	■ Wastewater Treatment Plant ■ Waste Treatment Centre ■ Leachate Evaporation Ponds

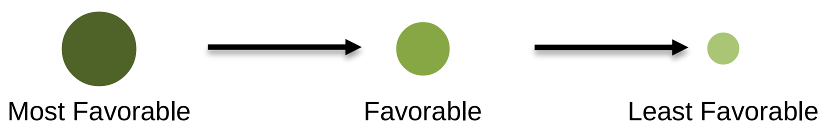
2.5.1 Evaluation Criteria

To determine the preferred or most favourable means of developing a disposal facility, each alternative is evaluated first for its technical feasibility. For those alternatives deemed technically feasible, a comparison of economic feasibility (i.e., cost) and the likely environmental effects is completed. Criteria for evaluating each of the alternatives are summarized in Table 2.5.1-1, with further rationale provided in the following sections.

Table 2.5.1-1: Criteria for Evaluating Alternatives

Category		Criteria
Technical Feasibility		■ Does the alternative meet the project purpose, as defined in Section 2.3? ■ Does the alternative meet the **schedule** (i.e., operational in 2020 to enable planned decommissioning and site restoration activities)? ■ Does the alternative meet the required **storage capacity** and is there potential for future **expandability**? ■ Is the alternative a **proven technology**? ■ Does the **design robustness** provide adequate provisions to protect the environment? ■ What is the **complexity of monitoring** requirements for the alternative?
Economic Feasibility		■ How does the **lifecycle cost** of each alternative compare in relation to each other?
Environmental Effects	Biophysical	■ **Environmental setting** - does the alternative result in new disturbance (i.e., Greenfield site) or is it located within a previously disturbed area (i.e., brownfield site)? ■ How do the likely **effects on biophysical valued components** compare (e.g., atmospheric environment, aquatic biodiversity, and terrestrial biodiversity)? ■ Can it be constructed, operated, and decommissioned in a manner that provides long-term **protection of ecological health**?
	Social	■ How do the **effects on socio-economic valued components** compare (e.g., land and resource use, heritage resources, socio-economic)?
Environmental Effects (continued)	Human Health & Safety	■ Can it be constructed/operated in a manner that provides **protection of public health and safety**? ■ How does the **long-term protection of public health and safety** compare? ■ Can it be constructed/operated in a manner that provides **protection of worker health and safety**?

The alternatives are described using the above criteria (where applicable) and are summarized in a matrix illustrating the relative preference of each alternative, as shown below. If the alternative has a high chance of successfully addressing a particular criterion, it is rated as most favourable. Similarly, if the alternative has a moderate likelihood of addressing a criterion, it is rated as favourable; while if the alternative is assessed as having a low likelihood of success or having unacceptable risk with a particular criterion, a least favourable rating is used.



2.5.1.1 Technical Feasibility

The following criteria were developed for the technical feasibility category.

- **Project Purpose –** The purpose of the NSDF Project is to substantially reduce the risks associated with the CNL legacy wastes, liabilities and the cost of laboratory operations to taxpayers in the 10-year period 2016 to 2025, inclusive, and to create the conditions for the revitalization of the CRL property. The most favourable alternative will satisfy the Project purpose, while the least favourable alternative will not satisfy the project purpose. Alternatives were considered to be favourable if they partially satisfied the project purpose.
- **Schedule –** To enable planned decommissioning and site restoration activities, the project must be operational and ready to accept waste by 2020; therefore, this criterion evaluated the likelihood of the alternative to meet this schedule. The alternative was considered to be most favourable if it was very likely the schedule could be met, favourable if there was a low risk that the schedule could not be met; and least favourable if it was unlikely the schedule could be met.
- **Disposal Capacity/Expandability –** The alternative must accommodate 1,000,000 m^3 of LLW and other wastes that meet the WAC. This volume is based on waste forecasting from future facilities and approaches to waste management. Alternatives that accommodated 1,000,000 m^3 and that provided future expandability were most favourable, while alternatives with adequate volume, but no option for future expandability were considered to be favourable. Alternatives that did not accommodate 1,000,000 m^3 of waste were least favourable.
- **Proven Technology –** This criterion evaluated the technology to be implemented with the alternative being considered. Proven technology was most favourable, while unproven technologies were considered to be favourable. An alternative was considered to be least favourable if the technology was disproven or outdated.
- **Disposal Facility Design Robustness –** This criterion considers the compatibility of the disposal facility construction materials with the radioactive wastes to be disposed as well as the design life of the facility. It is known that certain materials deteriorate over time when subjected to exposure to certain chemicals that may be contained in the leachate that is expected to be generated within the facility. The most favourable

alternative will use construction materials compatible with the radiological and chemical characteristics of leachate that is expected to be generated such that the facility will perform effectively for a 500-year or greater post-closure period. A favourable alternative includes use of construction materials that would result in the performance of the facility for less than a 500-year post-closure period. An alternative was considered to be least favourable if the construction materials were considered to be incompatible with the leachate and would result in deterioration of the construction materials during the operations phase or near-term post-closure period (i.e., less than 100 years).

- **Complexity of Monitoring –** This criterion considered the monitoring requirements that may be needed in support of each alternative. Standard monitoring requirements were considered most favourable, while a slight increase in monitoring requirements and/or complexity of the program was considered to be favourable. Least favourable alternatives were those that require complex or substantially increased monitoring requirements.

2.5.1.2 Economic Feasibility

The economic feasibility was evaluated by comparing the lifecycle cost estimate for each alternative. This estimate includes costs for excavation and construction of the facility and supporting infrastructure, operations, and ongoing monitoring and maintenance activities. Additionally, costs incurred during decommissioning and reclamation, and those associated with long-term monitoring and maintenance activities required during the post-closure period were also considered.

2.5.1.3 Environmental Effects

The evaluation of environmental effects is based on a qualitative comparison of biophysical and socio-economic effects on valued components (VCs) and potential effects on public and worker health and safety. Valued components refer to environmental features that may be affected by a project and that have been identified to be of concern by the proponent, government agencies, First Nation and Métis peoples, or the public (the Agency 2014). The selection of appropriate VCs allows the assessment to be focused on those aspects of the natural and human environment that are of greatest importance to society.

The list of VCs selected for the NSDF are described in Section 5.1, and considered a number of factors, including:

- presence, abundance and distribution within or relevance to the area associated with the NSDF;
- potential for interaction with the NSDF and sensitivity to effects;
- species conservation status or concern;
- ecological and socio-economic value to communities, government agencies and the public;
- traditional, cultural and heritage importance to First Nation and Métis peoples; and,
- experience with similar projects.

Environmental effects are evaluated for biophysical, social, and human health components. To facilitate comparison of potential environmental effects on VCs between the alternatives, effects are described by discipline; rather than for each individual VC. For example, VCs for the terrestrial biodiversity discipline include numerous species at risk and vegetation communities; however, for the alternatives assessment, environmental effects are evaluated for the terrestrial biodiversity discipline as a whole. The alternatives assessment considers effects on the biophysical (i.e., atmospheric environment, geological and hydrogeological environment, surface water environment, aquatic biodiversity, terrestrial biodiversity, and ecological health), social (socio-economic, land and resource use, and heritage resources), and human health and safety (i.e., public and worker) disciplines.

Environmental setting was included as an additional criterion in the evaluation of effects to the biophysical environment for alternatives (where applicable) The environmental setting criterion considered brownfield versus Greenfield site; namely whether construction would occur within existing disturbed or undeveloped area and within an impacted or non-impacted drainage basin. Development within an existing disturbed area and impacted drainage basin was considered most favourable, while construction within and undeveloped area and unimpacted drainage basin was favourable. Development within an environmentally sensitive area or that would affect significant cultural resources were considered to be least favourable.

2.5.2 Facility Type

Various types of disposal facilities have been constructed and are in operation around the world. These facility types have different degrees of containment and isolation capability appropriate to the radioactive waste that they will receive. However, regardless of the facility type selected, the specific aims of disposal remain the same according the IAEA Specific Safety Requirements (IAEA 2011):

- to contain the waste;
- to isolate the waste from the accessible biosphere and to reduce substantially the likelihood of, and all possible consequences of, inadvertent human intrusion into the waste;
- to inhibit, reduce and delay the migration of radionuclides at any time from the waste to the accessible biosphere; and,
- to confirm that the amounts of radionuclides reaching the accessible biosphere due to any migration from the disposal facility are such that possible radiological consequences are acceptably low at all times.

To meet the IAEA Specific Safety Requirements, CNL has defined the NSDF Project within its IWS as the primary disposal path for LLW and other wastes that meet the WAC.

The alternative facility type to the NSDF is a Geological Waste Management Facility (GWMF). The GWMF is a deep underground facility for disposal of the radioactive waste.

2.5.2.1 Near Surface Disposal Facility

2.5.2.1.1 Technical Feasibility

The IAEA definition of a near surface disposal is the emplacement of solid, or solidified, radioactive waste in a disposal facility located at or near the land surface (IAEA 2014). The preferred option for disposal of LLW and short-lived ILW is in near surface disposal facilities (IAEA 2001). A near surface disposal facility is a suitable and technically feasible means of disposing of LLW and ILW and the effectiveness of such facilities for disposal of LLW and ILW has been demonstrated as illustrated through the following near surface facilities currently in operation globally:

- LLW Repository near the Village of Drigg in Cumbria operated by United Kingdom (UK) Nuclear Waste Management Ltd (consisting of AECOM, Studsvik UK, and Areva) on behalf of the Nuclear Decommissioning Authority.
- Four commercial LLW disposal facilities in the United States, namely:
  - Waste Control Specialists in Andrews, Texas;
  - Energy Solutions facility in Barnwell, South Carolina;
  - Energy Solutions facility in Clive, Utah; and,
  - US Ecology Washington's site at Hanford, near Richland, Washington.
- United States Department of Energy Facilities and National Laboratories on-site disposal facilities:
  - Idaho CERCLA[1] Disposal Facility at the Idaho National Laboratory, Idaho;
  - Environmental Management Waste Management Facility at the Oak Ridge National Laboratory, Tennessee;
  - Fernald Environmental Management Project – On-Site Disposal Facility near Hamilton, Ohio; and,
  - Environmental Restoration and Disposal Facility at Hanford Site, Washington.

Within Canada, CNL is implementing the Port Hope and Port Granby Projects, on behalf of the Government of Canada, in eastern Ontario for the safe, long-term management of historic LLW arising from the operations of the former Eldorado Nuclear Ltd. These projects are building near surface engineered mounds for the storage of LLW that are similar in design that that proposed for the NSDF.

The NSDF Project entails design, licensing, procurement and construction, followed by operation. The time required to complete the activities that precede operation are expected to take four to five years. Given that work on the NSDF Project commenced in 2015, the schedule requirement to place the facility in operation by 2020 is achievable.

The ECM will comprise 10 cells; the first six cells will provide 525,000 m^3 capacity for CNL waste; and the remaining four cells will provide 475,000 m^3 for a total of 1,000,000 m^3. The NSDF will be developed in two phases with the first six ECM cells built and ready to accept waste in 2020. The phase one operating period

[1] CERCLA is an abbreviation for Comprehensive Environmental Response Compensation Liability Act

will extend from 2020 to 2045. Therefore, the NSDF Project meets the schedule and will allow for the planned accelerated decommissioning and site restoration activities. The four remaining ECM cells will be built in the 2040 to 2045 timeframe as part of the second phase of development and be operated for the period 2045 to 2070. The NSDF Project will create the disposal capacity required to satisfy the project purpose and allow for the planned accelerated decommissioning and site restoration activities. The NSDF is expandable by design and is being developed on a Greenfield site.

The NSDF Project will be designed as a permanent disposal facility, incorporating proven technologies and best industry practices, including documented experience from the IAEA and other similar national and international facilities (as described above). In accordance with IAEA Requirement 5 of SSR 5 (IAEA 2011), the NSDF Project would also be sited, designed and operated to provide features that are aimed at the isolation of the radioactive waste from people and the environment. Subsurface investigations have concluded that the geology and hydrology on the selected CRL site is acceptable for the construction and operation of the near surface facility. Designed and operated in accordance with applicable codes and best practices, the NSDF technology will feature a multi-layer, base-liner cover system to encapsulate the waste, a WWTP with dual process trains to treat the leachate generated within the ECM, and robust safety monitoring systems (e.g., leak detection, radiation monitoring and environmental monitoring) to assure the safety of workers and the public and the protection of the environment during the operations and post-closure periods.

The safety of the NSDF post-closure is provided by means of passive features (e.g., ECM cover system) that will end the need for active management, which is in alignment with IAEA Requirement 5 of SSR 5 (IAEA 2011. The features of the selected site and the performance of the combined natural and engineered barriers assure safety following the closure of the ECM (IAEA 2014). In addition, institutional controls, including restrictions on land use, and a program for monitoring will be completed in the post-closure period to demonstrate long-term safety of the public and the environment.

In summary, the NSDF Project addresses all of the relevant Technical Feasibility criteria set out in Table 2.5.1-1.

2.5.2.1.2 Economic Feasibility

The estimated cost of constructing the NSDF (Phase 1 – 525,000 m^3) is approximately \$215 million (M) (2016 Class 2 estimate). This estimate includes site preparation and construction of the engineered containment mound, waste water treatment plant, site development and infrastructure and support facilities. Future expansion of the engineered containment mound (Phase 2) for an additional waste capacity of 475,000 m^3 (including installation of covers) will cost approximately \$110 M.

Operating costs associated with a 50-year operating life, site closure costs and surveillance and long-term maintenance costs for a 30-year period following end of operations are estimated at \$275 M. This cost is broken down into \$240 M for 50 years of operation and maintenance including replacement of operational equipment, \$5 M for surveillance and long-term maintenance (30 Years beyond the 50 Years Operation), and \$30 M for final disposition costs.

This results in a total lifecycle cost of approximately \$600 M for the NSDF alternative, which is more than an order of magnitude less than the cost of a GWMF alternative. The reduced cost is more preferable as it further contributes to the reduction of the cost of laboratory operations to the Government of Canada and Canadian taxpayers.

2.5.2.2 Geologic Waste Management Facility

2.5.2.2.1 Technical Feasibility

A GWMF provides an alternative to the NSDF Project as proposed. Geological waste management facilities are designed for the long-term management of LLW, ILW and HLW. Wastes are processed and packaged for disposal in deep underground repositories in stable geological formations.

While there are no GWMFs currently operating in Canada, the US Department of Energy's Waste Isolation Pilot Plant (WIPP), a deep geologic repository (more than 700 metres (m) deep) for transuranic waste, has been in operation since 1992. Internationally, there are a number of GWMFs that are either under construction or with licence applications to construct under regulatory review, including:

- Finland's deep geologic repository for used fuel from Olkiluoto and Loviisa, approximately 400 to 450 m below ground in the Olkiluoto bedrock, as proposed by Posiva.
- Sweden's Spent Fuel Repository (SFR) for operational wastes (up to ILW) near Forsmark, Sweden, approximately 500 m below ground. Sweden is also proposing an underground repository for HLW disposal.
- A proposed 500 m deep geological repository complex in clay at Bure, France for HLW and long-lived ILW.
- Ontario Power Generation's (OPG) proposed Deep Geological Repository (DGR) for LLW and ILW on the Bruce Site in Tiverton, Ontario, approximately 680 m below ground surface.

In addition, China, Germany, India, Japan, Switzerland, the United Kingdom, United States and Canada are also pursuing geologic repositories for the long-term management and disposal for used fuel and other HLW. The use of GWMF as the preferred disposal solution is primarily for HLW and long-lived ILW, where additional barriers for protection are warranted.

Canadian Nuclear Laboratories has conducted assessments of its site geology and confirmed that the geologic characteristics required for a GWMF are present on CRL property. Significant surface and subsurface investigations including a total of 12,311.4 m of borehole drilling, core logging, geological mapping, geophysical surveys, hydrogeological surveys, and various geotechnical tests were performed on the CRL site since the 1970s to examine the suitability of the crystalline bedrock to host a Geologic Waste Management Facility (GWMF) for the permanent disposal of CNL's Intermediate Level Waste (ILW) at a depth between 500 and 1,000 m. Both shallow boreholes (<300 m) and deeper boreholes (~1,200 m) were drilled as part of the investigations.

Information derived from characterization activities was used to define bedrock structures on both macroscopic and mesoscopic scales. A descriptive hydrogeological model of the CRL site was developed, outlining the hydrogeological properties and 3D spatial distribution of all important hydrogeological units and features within the bedrock of the CRL site. The rock mass characterization conducted to date provides a reasonable basis for a positive decision to proceed to siting studies for a GWMF at the CRL site. As for the GWMFs discussed above, CNL would need to undertake comprehensive siting assessments and develop a robust design that protects the environment.

The timeline for developing a GWMF is difficult to accurately predict. Based on international experience, a licensing period of at least five years (likely longer) can be reasonably be expected. Following receipt of a licence to construct a GWMF, the development time to operation is four to six years. This includes the duration for site preparation, construction of surface facilities, shaft or ramp-sinking activities, underground lateral development, and commissioning. As such, the GWMF cannot be ready by 2020 to meet the project schedule and planned decommissioning and risk and liability reduction would be deferred.

Because GMWFs are built subterranean, provided suitable geology is available, there are no practical limitations on the size of the repository. As such, the GWMF can be designed to provide a total waste volume of 1,000,000 m^3; however, future expansion, if required, would be very expensive.

In GWMFs, isolation is provided primarily by the host geological formation and the depth of disposal. The passive safety features (barriers) of the GWMF design have to be sufficiently robust so as not to require repair or upgrading, in keeping with requirements that disposal facilities for radioactive waste not rely on active institutional control (IAEA 2011). However, institutional controls may contribute to safety by preventing or reducing the likelihood of human actions that could inadvertently interfere with the waste or degrade the safety features of the GWMF. In addition, a program for monitoring would be needed in the post-closure period to demonstrate long-term safety of the public and the environment.

In summary, the GWMF facility type meets most technical feasibility criteria, as set out in Table 2.5.1-1. The GWMF has been demonstrated to provide an adequate level of environmental protection through international experience (as described above). It would satisfy the project purpose; however it would not meet the schedule requirements. It would provide the needed storage capacity and offer expandability at a high cost. The technology for GWMFs is proven and a robust design with monitoring systems that meet international requirements for disposal facilities could be developed at the CRL site based on available geologic data.

2.5.2.2.2 Economic Feasibility

The costs associated with constructing a GWMF are considerably higher than a NSDF. Similarly, the operating costs for a GWMF would also be greater than that of the NSDF due to the need for additional waste packaging and handling of all waste. For example, the total waste volume to be disposed in OPG's DGR Project is 200,000 m^3 of LLW and ILW (OPG 2011a). The estimated capital costs for this project are $1,000 M (OPG 2011a). Annual operating costs are estimated at $25 M (Golder 2004). Using these values, the inferred lifetime expenditure for a GWMF with a total waste volume of 1,000,000 m^3 and 50-year operational phase could be greater than $10,000 M, which is more than 36-times greater than the cost of the NSDF alternative.

2.5.2.3 Environmental Effects

The key pathways by which a NSDF or GWMF may interact with the environment is through surface water and groundwater intrusion, migration of contaminated water (leachate), inadvertent intrusion, escape of radioactive gas to the atmosphere, and disturbance to the terrestrial environment from the project footprint. Regardless of whether the facility is a NSDF or GWMF, engineered barriers and mitigation measures will be implemented to prevent or delay the migration of contaminants, protect human and ecological health, and limit effects to the aquatic and terrestrial environments. These barriers and mitigation measures represent an important component of the safety from the operational phase through the period of Institutional Control.

The majority of effects to air quality would occur during the construction and operational phases for both alternatives. Blasting activities would be required for the construction of both an ECM and a GWMF and fugitive dust emissions would be generated during earth moving activities. During operations and post-closure of the ECM, radioactive gases (e.g., radon and tritium) and radioactive particulates may be released from the wastes within the facility during the operations and post-closure phases. During operations, there would be differences in atmospheric emissions between the two alternatives; the ECM would have heavy equipment placing wastes and cover material at surface, whereas the majority of the equipment during operations of the GWMF will be below ground, and emissions managed through ventilation shafts. Both alternatives would have different types of effects on air quality; they would each implement mitigation that provides for worker and public health and safety and protection of the environment. Greenhouse gas emissions are expected to be of the same order of magnitude for both alternatives.

Potential effects on hydrogeology are related to the alteration of groundwater levels and flows due to the construction of the facility and potential changes to groundwater quality due to migration of leachate following post-closure activities. Subsurface investigations on CRL property have concluded that the geology on-site is acceptable for the construction and operation of an ECM. The surface geology of the CRL site is composed of four types of glacial and post-glacial sediments including till, water-deposited sands (fluvial), wind-deposited (Aeolian) sands and organic deposit. To limit potential effects to groundwater, engineered barriers to control for infiltration of surface water, groundwater intrusion, and migration of contaminated water (leachate), would be implemented. Engineered barriers can be used as physical and/or chemical obstructions and can provide either partial containment or complete isolation of the waste or both (IAEA 2001).

In GWMF facilities, the waste is normally placed below the ground water table and will thus have a water saturated environment outside the engineered barriers soon after closure of the repository (Argonne National Laboratory 2011). A study has been performed (CRL 2011) to gather sufficient facts for the resultant geoscientific interpretations and analyses to determine whether or not suitable bedrock conditions likely exist at CRL for a GWMF. Hydraulic testing was completed which suggests that intrablock regions of the CRL rock base is generally low to very low below the 400 to 500 m depth. In accordance with the groundwater-flow models, the deeper bedrock at the CRL site appears to be able to provide moderately strong natural barrier against transport of contaminants from a GWMF. In summary, although both alternatives would be designed to be protective of groundwater; a GWMF is considered to be more favourable as it would provide additional barriers against potential groundwater transport.

Both facility types may affect existing availability of the spatial and temporal distribution of water quantity for aquatic and terrestrial ecosystems. For both the NSDF and GWMF facility types, surface water drainage would be managed within the project footprint. Proposed design features would be based on proven surface water management practices controlling erosion, capturing sediment, and for safely conveying flows associated with a 1:100-year or regional storm event. Because the GWMF design would not be prone to infiltration of precipitation through the waste during emplacement, only the NSDF alternative would require some form of water treatment to mitigate potential effects to surface water quality associated with the seepage of leachate from the facility (i.e., changes to groundwater quality). The NSDF's water treatment facility would be designed to meet site-specific risk-based effluent quality criteria to be protective of the environment and humans. In conclusion, there are no anticipated differences between the NSDF and GWMF alternatives when considering potential effects to the surface water environment from each facility except the infiltration of water to the waste and related need for treatment to mitigate effects.

Potential effects to terrestrial biodiversity are primarily related to the amount of surface disturbance to vegetation and wildlife habitat. The disturbance footprint for a NSDF facility large enough to accommodate 1,000,000 m^3 of LLW alternative is approximately 34 hectares (ha). The surface footprint required for a GWMF is dependent on the size of the underground repository and the volume of waste rock to be managed at surface. As a comparison, the surface footprint required for the DGR Project is approximately 30 ha for management of 200,000 m^3 of waste (OPG 2011a). Therefore, the footprint required for waste rock management at the CRL property for 1,000,000 m^3 could be much larger. This larger footprint would result in greater indirect effects on the terrestrial environment. However, in both cases, mitigation will be implemented to eliminate or reduce potential effects on Species at Risk that may be found or critical habitat.

As previously mentioned, the objective of the design of a disposal facility is to ensure the facility can be built and the waste received, handled, and disposed without undue risk to human health and the environment, both during facility operation and after facility closure. There are numerous examples of both NSDF and GWMF type facilities that have been successfully constructed and operated. Within Canada, CNL is implementing the Port Hope and Port Granby Projects for the safe, long-term management of historic LLW arising from the operations of the former Eldorado Nuclear Ltd. These projects are building near surface disposal facilities similar to the design proposed for the NSDF Project. Results of the annual radiation dose assessment found that Port Hope Project-related incremental radiation doses to all area and adjacent receptors during construction and operations are less than or equal to 25% of the CNSC dose limit of 1 millisievert per year (mSv/y) for members of the public (Golder 2005). Radiation doses to members of the public for the long-term maintenance and monitoring phase are predicted to be indistinguishable from the existing conditions (Golder 2005).

A detailed safety assessment, performed for OPG's Deep Geologic Repository Preliminary Safety Report (OPG 2011b), concluded that the results of the analysis indicate very low doses to the public, far below the CNSC regulatory limit of 1 mSv/y. A preliminary post closure performance and safety assessment for the long-term management of low and intermediate-level waste in a GWMF type facility examined the long-term evolution of the performance post-closure. Results from the simulation showed that estimated dose rates were orders of magnitude below 0.3 millisieverts (mSv), and concluded that there were no results found which would preclude the safe disposal of the six low-level and intermediate-level waste groups which were used in this study. For a similar GWMF facility (OPG's Deep Geologic Repository) for the human intrusion scenario, a borehole is drilled into the repository and gases and material are not appropriate stored are released (OPG 2011a). The calculated doses were estimated to be about 1mSv for the future person farming on the site. However, the likelihood of inadvertent human intrusion into the waste will be low as a consequence of the chosen depth for a GWMF (IAEA 2011).

Regardless of the type of facility, the design would aim to ensure that such releases do not exceed applicable regulatory limits during either the operational or post-closure phases and are protective of humans and the environment. However, given the nature of the GWMF located at a nominal depth, this facility type may be considered slightly more robust against surface activities and therefore is slightly more favourable.

Both a NSDF and GWMF facility type would meet all regulations and be constructed in a manner that protects worker health and safety. Operations at the NSDF will be similar to those applied by CRL at the WMAs for over 60 years. It is expected that the majority of environmental remediation and decommissioning waste will be disposed as bulk material, in unpackaged form. Only about 15% of NSDF waste will have sufficiently high radionuclide content to require use of containers. The waste delivered to the NSDF will not require packaging or

repackaging at the facility. Conversely, increased packaging would be requirements for a GWMF, and the additional handling and packaging of wastes may result in increased exposure to workers. As indicated in the CRL GWMF study (CNL 2011) the degree of component dismantlement and size reduction is dependent on many factors, including accessibility. For a similar facility, OPG DGR (OPG 2010), all LLW and ILW shall be shipped or transferred to the DGR facility in disposal ready form that is in supplied/approved waste containers, will not require repackaging at the facility. From a worker health and safety perspective, the repackaging of waste into approved packages is a dose significant task. The design process provides for worker health and safety by maintaining occupations exposures ALARA regardless of which facility type is selected; however, because of the reduced handling and packaging requirements, the NSDF type facility is most favourable.

Overall, mitigation through the implementation of the above described engineered barriers for an NSDF or GWMF facility are anticipated to reduce or limit environmental effects and subsequently risk to human and environmental health. Effects to ecological health are expected to be similar between alternatives (e.g., air and dust emissions and employment and business opportunities generated for both design options are assumed to be similar; both design options would avoid lakes and streams, sensitive and/or critical habitat, and significant cultural resources, and both would require restrictions on future land use).

2.5.2.4 Summary

Both the NSDF and GWMF alternatives meet CNL’s overall need and are environmentally feasible options. However, the GWMF does have substantially higher lifecycle costs, which are potentially an order of magnitude higher than for an NSDF. In addition, the environmental studies required to confirm site suitability, licencing, and construction schedule are substantially longer than that required for the NSDF alternative and would result in a construction start date later than 2020, delaying planned decommissioning of facilities at CRL. A GWMF would provide increased barriers for potential releases to the environment in the long-term, but would also require additional waste handling for emplacement. Near surface disposal facilities have been demonstrated globally as an effective disposal solution for the volume and nature of wastes proposed for this project. Geologic waste management facilities are most typically proposed for HLW and ILW, and the increased protection to the environment is marginal relative to the nature of the wastes (i.e., approximately 99% by volume LLW) and protection offered through a NSDF. Therefore, a NSDF is the most feasible and most favourable alternative.

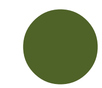
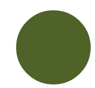
Table 2.5-2: Evaluation of Alternatives – Facility Type

Criteria	Alternative 1 – Near Surface Disposal Facility (NSDF)		Alternative 2 – Geologic Waste Management Facility (GWMF)	
Technical Feasibility				
Project Purpose	The NSDF satisfies the project purpose and allows for the planned accelerated decommissioning and site restoration activities, liabilities and the cost of laboratory operations to taxpayers in the 10-year period 2016 to 2025.		Construction of a GWMF partially satisfies the project purpose in that it would substantially reduce the risks and liabilities associated with the CNL legacy wastes; however it does not reduce the cost of operations to the taxpayers, nor does it meet the 2016 to 2025 accelerated timeframe.	
Schedule	Phase one of the development will involve construction such that the facility will be ready to accept waste in 2020.		Commissioning for a GWMF typically take four to six years, and would delay the start of operations beyond 2020.	
Storage Capacity/ Expandability	The first phase allows construction of cells for the disposal of 525,000 m^3 of CNL waste; and the second phase will expand the ECM to provide a total waste volume of 1,000,000 m^3. Further expansion would be possible if required		The GWMF can be designed to provide a total waste volume of 1,000,000 m^3; however, future expansion would be more expensive	
Proven Technology	The effectiveness of both alternatives for disposal of LLW and ILW has been demonstrated through similar facilities currently in operation globally.			
Design Robustness	The near surface disposal facility incorporates proven technologies and best industry practices, including documented experience from the IAEA and other similar national and international facilities. It is the performance of the combined natural and engineered barriers that provides safety after closure for the NSDF.		Conceptually, a GWMF has been demonstrated to provide an adequate level of environmental protection through international experience, thus is considered to be robust and technically feasible. The natural geologic barrier of a GWMF provides additional isolation of the wastes, as compared to a NSDF.	
Monitoring Complexity	No anticipated difference between alternatives.			

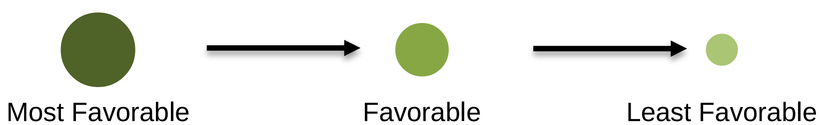
Table 2.5-2: Evaluation of Alternatives – Facility Type

Criteria	Alternative 1 – Near Surface Disposal Facility (NSDF)		Alternative 2 – Geologic Waste Management Facility (GWMF)	
Economic Feasibility				
Lifecycle Cost	$600 M		$10,000 M	
Environmental Effects				
Biophysical				
Atmospheric Environment	No anticipated difference between alternatives.			
Geological and Hydrogeological Environment	Engineered barriers to control for infiltration of surface water, groundwater intrusion, and migration of contaminated water (leachate), would be implemented.		The natural geologic barrier of a GWMF provides additional isolation of the wastes, as compared to a NSDF.	
Surface Water Environment	There are no anticipated differences between the alternatives.			
Aquatic Biodiversity	There are no anticipated differences between the alternatives.			
Terrestrial Biodiversity	The footprint required for a NSDF is anticipated to be 34 ha; however, mitigation will be implemented to eliminate or reduce potential effects on Species at Risk that may be found or critical habitat.		The footprint required for waste rock management of a GWMF could be much larger.	
Ecological Health	No anticipated difference between alternatives.			
Social				
Socio-economics	No anticipated difference between alternatives.			
Land and Resource Use	No anticipated difference between alternatives.			

Table 2.5-2: Evaluation of Alternatives – Facility Type

Criteria	Alternative 1 – Near Surface Disposal Facility (NSDF)		Alternative 2 – Geologic Waste Management Facility (GWMF)	
Human Health and Safety				
Public Health & Safety (construction and operations)	Both alternatives can be developed in a manner that protects public health and safety during construction and operations.			
Public Health & Safety (long-term)	Institutional controls, including restrictions on land use, and a program for monitoring will be completed in the post-closure period to demonstrate long-term safety of the public and the environment.		Institutional controls, including restrictions on land use, and a program for monitoring will be completed in the post-closure period to demonstrate long-term safety of the public and the environment. However, given the nature of the GWMF located at a nominal depth, human intrusion is less likely	
Worker Health & Safety	Because of the reduced handling and packaging requirements, the NSDF type facility is most favourable		The repackaging of waste into approved packages is a dose significant task.	

Notes:



2.5.3 Facility Design

According to the IAEA *Technical Considerations in the Design of Near Surface Disposal Facilities for Radioactive Waste* (2001), the following are fundamental design principles relating to the safe management of radioactive waste and disposal.

- Protection of human health – radioactive waste shall be managed in such a way as to secure an acceptable level of protection for human health.
- Protection of the environment – radioactive waste shall be managed in such a way as to provide an acceptable level of protection of the environment.
- Protection of future generations – radioactive waste shall be managed in such a way that predicted effects on the health of future generations will not be greater than relevant levels of effects that are acceptable today.
- Burdens on future generations – radioactive waste shall be managed in such a way that will not impose undue burdens on future generations.
- Safety of facilities – the safety of facilities for radioactive waste management shall be appropriately assured during their lifetime.

Consistent with the above principles, the objective of the design of a near surface disposal facility is to ensure the facility can be built, operated, and managed following its closure without undue risk to human health and the environment (IAEA 2001). All types of near surface disposal rely on a system of passive engineered and natural barriers to prevent, or delay, the transport of radionuclides into the environment; however, the specific features and characteristics of the protective barriers may differ significantly between various facilities (Argonne National Laboratory 2011). For example, engineered barriers, such as liners, vaults and covers are ways to provide containment and prevent water from entering into the disposal facility.

This section evaluates the proposal of disposing waste within an Above-ground Concrete Vault (AGCV) as an alternative to an ECM design. When evaluating the technical feasibility of the AGCV and ECM facility design, many of the criteria can be satisfied by both alternatives. For example, both alternatives can be constructed such that they meet the purpose of the project and the required project start date (i.e., 2020). In addition, both alternatives can be constructed to accommodate 1,000,000 m^3 of radioactive waste and both allow for future expandability, if required. The AGCV and ECM facility designs are proven technologies and there are several international examples of each. Both have relatively moderate technical requirements for the site and it is not overly difficult to find suitable places to locate them. The monitoring requirements for these surface-located options can be expected to be similar and employ conventional environmental technologies. The main differences in the alternatives are related to design robustness, lifecycle costs, and potential environmental effects; as such, the evaluation focuses on these criterion.

2.5.3.1 Engineered Containment Mound

2.5.3.1.1 Technical Feasibility

Disposal facilities constructed on the surface, typically in the form of a mound or hill, primarily use engineered barriers to prevent water from infiltrating the disposed waste, thus maintaining diffusion-controlled transport of radionuclides, which is an extremely slow process (Bergman 2006). To meet the above-mentioned design

principles and objectives, the ECM design features composite final cover and base liner systems comprising natural and synthetic materials. The base liner contains both engineered leachate collection and leak detection systems as well as natural drainage elements. The performance of the ECM will be monitored to provide early indications of any need for maintenance or repair.

The final cover system for the ECM incorporates a composite high-density polyethylene (HDPE) geomembrane underlain by a geosynthetic clay liner (GCL). Above the HDPE geomembrane are granular materials and clear stone to support drainage, and armour stone to deter human intrusion, tree rooting and burrowing (by animals). The grassy top layer of the cover system prevents erosion and is shaped/sloped to direct the run-off of precipitation (IAEA 2001). The base liner system design incorporates redundancy in that the primary composite base liner consists of a HDPE geomembrane underlain by a GCL and the secondary composite liner consists of a HDPE geomembrane underlain by both a GCL and a compacted (natural) clay liner. The leachate collection piping within the primary liner, and the leachate detection system in the secondary liner, both serve to collect and efficiently transport water that has infiltrated the cover and the waste out of the mound (to exterior sumps). The granular materials and clear stone layers within the liner system also facilitate water movement to the systems that will remove it from the ECM. The design of the ECM for the NSDF Project is fundamentally consistent with those for the Port Granby and Port Hope Low-Level Radioactive Waste Facilities now under construction.

An advantage of this mound-type repository design is that the waste is emplaced above the groundwater table and the waste stays dry as long as the protective barriers are intact, which may be on the order of hundreds of years (Argonne National Laboratory 2011). These mound-type disposal facilities also have relatively moderate technical requirements for the site, so it is usually easy to find places to locate them. For proposed ECM, sand will be used to fill the space between the waste packages. This type of fill material will allow water to rapidly drain through the waste, but will help to stabilize the waste packages in the ECM. This added stability is also important in the long-term as the waste packages degrade and the final cover settles. These fill materials also allow easy removal of the waste, if such action ever became necessary after disposal. Although ECM facilities may require extensive monitoring requirements; these monitoring programs are relatively straight forward and similar programs are currently in place at CRL site.

The main disadvantage for surface disposal is that the protective cover of the waste is exposed to weathering and erosion that can endanger the integrity of the repository. The cover is designed to divert the precipitation away from the ECM. Available literature on geomembrane service life under the conditions expected for the ECM (i.e., temperature, leachate quality, radiation and stresses) indicates that HDPE geomembrane liner (i.e., primary composite liner and final cover liner) is expected to remain functional over the 500-year post-closure design life of the ECM. The cover liner is also the feature of the facility that is the easiest and cheapest to repair, replace, or to cover over if infiltration does occur.

2.5.3.1.2 Economic Feasibility

The estimated cost to build (i.e., capital expenditures,) the NSDF for the 1,000,000 m^3 of CNL waste is $250 M. This estimate includes site preparation and construction of the engineered containment mound, supporting facilities and buildings, and access roads. Operating costs associated with a 50-year operating life, site closure costs and surveillance and long-term maintenance costs for a 30 year period following end of operations are estimated at $580 M. This results in a total lifecycle cost of $600 M for the NSDF Project.

2.5.3.2 Above-ground Concrete Vaults

2.5.3.2.1 Technical Feasibility

Above-ground Concrete Vaults are another type of near surface disposal facility employing engineered multi-barrier concrete structures set partially into the ground. With this technology, isolation is provided by a reinforced-concrete building constructed on the surface. Waste containers may be loaded into a vault through an open side or top, which is sealed after the vault has been filled. Concrete containment vaults add structural stability to the disposal unit, help to prevent any infiltrating water from coming in contact with the waste and provides an intrusion barrier around the waste. The waste in the building would be isolated from humans and the environment as long as the integrity of the building is maintained. Although AGCV facilities may require extensive monitoring requirements; these monitoring programs are relatively straight forward and similar programs are currently in place at CRL site.

The AGCV types of disposal facilities are not as heavily impacted by weathering and erosion, when compared to the ECM-type; however, there are disadvantages (Argonne National Laboratory 2011). Above-ground facilities are subject to deterioration through exposures to wind, rain, and freeze-thaw cycles and are vulnerable to cracking as a result of uneven settlement and seismic events. While some of these trigger events could be mitigated by earth covers surrounding the AGCV, not all can be reduced. Cracks, for example, that develop in the concrete provide pathways for water infiltration and the migration of radionuclides out of the containment afforded by the AGCV. Design features such as reinforcement, expansion joints, sealants and drainage collection would serve to mitigate the impacts of these forces. Further, concrete has been extensively studied and can be made durable enough to last for a few hundred years and perhaps longer (U.S. Congress, Office of Technology Assessment 1989). Some predictive models even indicate that concrete will last longer than 1,000 years; however, beyond about 500 years, the uncertainty of such predictions increases (U.S. Congress, Office of Technology Assessment 1989). Lastly, inadvertent human intrusion is more likely therefore Institutional Control measures must be stronger.

There are several international examples of the use of AGCV, including facilities in France and Spain. The facility located at Centre de l'Aube in France, which began operations in 1992, has been designed to be Europe's largest repository for LLW and ILW. Waste are placed in concrete vaults constructed on the surface under a movable shelter that protects the wastes from weather during placement. Once a vault is full, a concrete cover is poured in place to completely isolate the waste from the environment.

2.5.3.2.2 Economic Feasibility

The construction cost estimate for AGCV option was developed from the 1999 Organization for Economic Co-operation and Development report titled *Low Level Waste Repositories: An Analysis of Cost* (OECD 1999) using information from El Cabril facility for LLW in Spain. The construction cost, including research and development, site screening, facility design, 28 disposal vaults, supporting buildings and facilities, for a 100,000 m^3 facility was approximately $229 M Canadian (CAD 2016), plus $762 for every additional cubic metre of waste. For CNL waste volume of 1,000,000 m^3, the cost to construct a concrete vault design would be approximately $900 M, which is considerably higher than the ECM design. Annual operating costs are estimated at $2,500 per cubic metre of waste emplaced (present day value) (OECD 1999). Using these values, the inferred lifetime expenditure for the Above-ground Concrete Vaults with a waste volume of 1,000,000 m^3 and 50-year operational phase is estimated. This results in a total lifecycle cost of $3,400 M ($900 M for construction and $2,500 M operations); more than a factor of five greater than the NSDF alternative.

2.5.3.3 Environmental Effects

The pathways by which contaminants from a NSDF may migrate or be brought into contact with humans and biota is through infiltration of surface water, groundwater intrusion, migration of contaminated water (leachate), inadvertent intrusion and escape of radioactive gas (IAEA 2001). Regardless whether the facility incorporates an ECM or AGCV, engineered barriers will be implemented to prevent or delay the migration of contaminants via these pathways. These barriers represent an important component of the NSDF safety from the operational phase through the period of Institutional Control. The design of the NSDF will provide that all safety and regulatory requirements are met such that the ECM or AGCV would be constructed and operated in a manner that is safe to the public and workers.

Engineered barriers to control for infiltration of surface water, groundwater intrusion, migration of contaminated water (leachate), inadvertent intrusion and escape of radioactive gas for the ECM include installation of a primary and secondary liner, and a final cover at closure. For the ECM, most of the waste placed in the facility will be unpackaged (i.e., loose/bulk); although some wastes may be packaged (e.g., in high integrity containers) to provide additional containment. Most of the waste to be disposed will arise from the decommissioning of buildings and is lightly contaminated and safe to be disposed in bulk form (i.e. without double-handling and packaging). Reducing unnecessary processing and packaging decreases potential exposure and risk to workers.

The AGCV facility is constructed of reinforced concrete that offers structural stability and provides an intrusion barrier around the waste. The AGCV also deters infiltration of water to the wastes. The footprint required for the AGCV is 1.5 to 2 times that required for an ECM due to the need to package all waste for an AGCV and constraints on the stacking of waste packages. Based on constructible areas available at the CRL site, it would be necessary to develop at least two sites/locations to establish disposal capacity for 1,000,000 m^3 of waste in an AGCV type facility. Developing multiple sites would have a greater biophysical impact.

Overall, mitigation through the implementation of the above described engineered barriers for an ECM or AGCV facility are anticipated to reduce or limit environmental effects and subsequently risk to human and environmental health. Effects to all other VCs are expected to be similar between alternatives (e.g., air and dust emissions and employment and business opportunities generated for both design options are assumed to be similar; both design options would avoid lakes and streams, sensitive and/or critical habitat, and significant cultural resources, and both would require restrictions on future land use). Because the pathways through by which contaminants may migrate or be brought into contact with humans and biota are similar for both alternatives, similar monitoring programs would also be required during operations and through the Institutional Control period to demonstrate long-term safety of the public and the environment.

2.5.3.4 Summary

As summarized in Table 2.5-3, although both alternatives are technically and environmentally feasible, the costs associated with building an AGCV design is higher (almost four times greater than ECM). In addition, the additional packaging and containment is not required for the type of waste that is intended to be disposed in the proposed ECM on the CRL property. Therefore, the most favourable alternative facility design for the NSDF is an ECM.

Table 2.5-3: Evaluation of Alternatives – Facility Design

Criteria	Alternative 1 – Engineered Containment Mound (ECM)		Alternative 2 – Above-ground Concrete Vaults (AGCV)	
Technical Feasibility				
Project Purpose	Both alternatives meet the technical requirements.			
Schedule	Both alternatives can be constructed to meet the Project start date.			
Storage Capacity/Expandability	The ECM requires 16 ha to contain 1,000,000 m^3 of radioactive waste within the engineered mound, and approximately 20 additional ha for the WWTP, support facilities and site infrastructure. All NSDF Project elements can fit on a single site on the CRL property.		The AGCV would require 1.5 to 2 times the spatial area of an ECM for the disposal of the same quantity of waste. The concrete vault has limitations on stacking of waste containers resulting in a larger footprint needed to contain CNL's 1,000,000 m^3 volume. Chalk River Laboratories does not have a site large enough for an AGCV sized to hold 1,000,000 m^3 of waste and would need to develop (at least) two sites.	
Proven Technology	ECM is a proven disposal technology and widely used internationally for disposal of LLW and can be shown to be a safe disposal option for other wastes that meet the WAC. The NSDF waste volume forecast is 99% LLW.		Above-ground concrete vaults area proven disposal technology and generally used for LLW. The AGCV offers a level of containment that exceeds the requirement for the vast majority of the NSDF waste volume forecast.	
Design Robustness	The ECM offers multiple engineered barriers including a double composite base liner system with redundant leachate systems, and a composite cover system. Natural and manmade materials are employed for liner robustness. The ECM's earthen construction offers good seismic protection.		The AGCV offers multiple engineered barriers that provide design robustness. These include high strength concrete structural elements and engineered packages for all wastes. Above Ground Concrete Vaults also offer greater protection from weathering and erosion compared to the ECM.	
Monitoring Complexity	Both alternatives may require extensive monitoring requirements; however, these monitoring programs are relatively straight forward and similar programs are currently in place at CRL site			

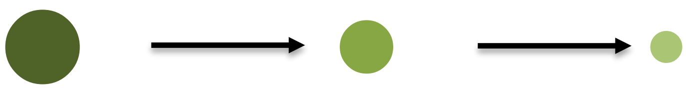
Table 2.5-3: Evaluation of Alternatives – Facility Design

Criteria	Alternative 1 – Engineered Containment Mound (ECM)		Alternative 2 – Above-ground Concrete Vaults (AGCV)	
Economic Feasibility				
Lifecycle Cost	$600 M		$3,400 M	
Environmental Effects				
Biophysical				
Atmospheric Environment	No anticipated difference between alternatives.			
Geological and Hydrogeological Environment	Engineered barriers would result in reduced releases of leachate to groundwater; however, release during post-closure is anticipated.		Additional engineered barriers would result in reduced releases of leachate to groundwater compared to an ECM; however, release during post-closure is anticipated.	
Surface Water Environment	No anticipated difference between alternatives.			
Aquatic Biodiversity	No anticipated difference between alternatives.			
Terrestrial Biodiversity	The disturbance footprint would be designed to avoid wetlands and limit disturbance to the natural environment to the extent feasible.		Above-ground concrete vaults are likely to have a larger footprint as a result of additional packaging requirements	
Ecological Health	No anticipated difference between alternatives.			
Social				
Socio-economic	No anticipated difference between alternatives.			
Land and Resource Use	No anticipated difference between alternatives.			

Table 2.5-3: Evaluation of Alternatives – Facility Design

Criteria	Alternative 1 – Engineered Containment Mound (ECM)		Alternative 2 – Above-ground Concrete Vaults (AGCV)	
Human Health and Safety				
Public Health & Safety (construction and operations)	Both alternatives can be developed in a manner that protects public health and safety in during construction and operations.			
Public Health & Safety (long-term)	Both alternatives can be developed in a manner that protects public health and safety in the long-term.			
Worker Health & Safety	Reduces unnecessary processing and packaging decreases potential exposure and risk to workers.		Additional processing and packaging increases potential exposure and risk to workers.	

Notes:



Most Favorable Favorable Least Favorable

2.5.4 Facility Location

The vast majority of the waste to be managed in the NSDF is located at CRL. When considering where to construct the NSDF, CNL also considered locating the facility at alternative sites operated by CNL, specifically Whiteshell Laboratories (WL) in Pinawa, Manitoba, and the NPD prototype reactor site in Rolphton, Ontario. The land at these sites is controlled by CNL and are likely to have suitable technical characteristics to safely manage the waste. Due to the additional costs and time required to procure and execute the project on lands outside of these, non-CNL owned and operated locations were not considered technically or economically feasible alternatives.

This section evaluates the proposal of disposing waste either at CRL or at WL or NDP. When evaluating the technical feasibility of the facility location, many of the criterion can be satisfied by both alternatives. For example, both alternatives can be constructed to accommodate 1,000,000 m^3 of LLW and both allow for future expandability, if required. It is anticipated that monitoring requirements would also be similar between the alternatives. Key differences in the alternatives are primarily related to project purpose and schedule; as such, the evaluation focuses on these criterion.

2.5.4.1 On-site Location at Chalk River Laboratories

2.5.4.1.1 Technical Feasibility

The CRL property (38.7 square kilometres [km^2]) extends approximately 6.5 kilometres (km) inland from the Ottawa River. The controlled Waste Management Areas (WMAs) and the unaffected areas on-site are located within the CRL property. The CRL Main Campus contains the majority of buildings, laboratories, and nuclear facilities on-site and is located close to the Ottawa River. More than 90% of the CNL waste to be managed in the ECM is already on the CRL property.

Subsurface investigations on CRL property have concluded that the geology on-site is acceptable for the construction and operation of an ECM. The surface geology of the CRL property is composed of four basic types of glacial and post-glacial sediments including till, water-deposited sands (fluvial), wind-deposited (Aeolian) sands and organic deposit.

Access within the CRL site is well established and upgrades required for heavy equipment and truck traffic would be minimal. Mandatory services (i.e., Class IV power, water for sanitary and process requirements, gas or other heating sources) are also readily accessible. There is the possibility of other projects being developed at the CRL site that may also reduce some of the costs associated with construction of the NSDF by combining efforts.

2.5.4.1.2 Economic Feasibility

As described in Section 2.5.3.1.2, the total lifecycle cost of an NSDF facility on the CRL site is $600M.

2.5.4.2 Off-site Location (CNL Sites excluding Chalk River Laboratories)

2.5.4.2.1 Technical Feasibility

The non-CRL off-site locations selected for the alternative means evaluation are those operated by CNL: Whiteshell Laboratories in Pinawa, Manitoba, and the Prototype Reactor Site NPD in Rolphton, Ontario. Both WL and NPD sites have sufficient area available on-site to accommodate the construction and operation of a NSDF facility with a storage capacity of 1,000,000 m^3. In addition, both locations may be geologically suitable

sites for a NSDF; however, geological studies would be needed to confirm the suitability of both the WL and NPD Sites for a NSDF.

Both NPD and WL sites are scheduled to be decommissioned by 2020 and 2024, respectively. As a result, these sites would need to continue to provide the physical services (i.e., Class IV power, water for sanitary and process requirements, gas or other heating sources, or other nuclear operating infrastructure) and management infrastructure required to support the operation of the NSDF for the 50 year operating period.

Shipping 1,000,000 m^3 of waste from CRL to WL at an average of 20 cubic metres per truck (m^3/truck) would result in 50,000 shipments. The potential environmental effects of transporting such large volumes by truck (i.e., 50,000 shipments travelling roughly 1,900 km from CRL to WL) or by rail will be greater than disposal in an on-site facility at CRL.

2.5.4.2.2 Economic Feasibility

Although both alternatives are assumed to have similar capital costs, extensive geological studies would be needed to confirm the suitability of both the WL and NPD sites for a NSDF, which is an added cost. Operations costs would also be much higher for an off-site facility as the majority of the wastes are located at CRL and would require packaging and transportation. In addition, management and maintenance of services would be higher for sites that would be otherwise decommissioned. Overall, the costs associated with transporting radioactive waste to an off-site facility makes this alternative less favourable. Transportation costs from CRL to WL by two possible means were approximated – by trucks and by rail. If CRL waste is approximated to weigh 2M tons and it is 1,900 km from Chalk River, Ontario to Pinawa, Manitoba (i.e., WL site), the cost of transporting waste would be approximately $135M, by truck, and $401M, by rail[2]. Eventual closure of the NSDF facility and post-closure monitoring and maintenance costs are assumed to be similar for both alternatives.

2.5.4.3 Environmental Effects

Potential effects to the atmospheric environment for both alternatives are related nuisance noise from construction activities, and increased air and greenhouse gas emissions from the transportation of waste to an off-site facility. The nearest population center to the CRL site is the Village of Chalk River, approximately 6 km west. The nearest residents are approximately 2 km from the WL site and are located along the Winnipeg River northwest of the site. The nearest population centers are the Village of Lac Du Bonnet, 9 km to the north and the Local Government District of Pinawa, 10 km to the east. The nearest population centers to the NPD site are Rapides des Joachims located 3 km northwest and Deep River located 17 km southeast. Individual residents of Laurentian Hills live within 1 km of the NPD site boundary. The closest resident property is at Point Stewart on the Ottawa River 1 km downstream of NPD site. Nuisance noise effects are expected to be greatest at NPD given the close proximity of the nearest resident (i.e., 1 km). Nuisance noise effects are anticipated to be related to the construction phase of the project and occur intermittently.

The bedrock in the region lies within the Grenville Province of the Canadian Shield and is Precambrian, predominantly monzonitic gneiss. The overburden of the CRL site consists of boulder, silty sand till deposited during the most recent glaciation, overlain with fine to medium sands. The till contains a wide range of size fractions, from large blocks of rock to fine silts and clay. The general geology of the region is the Precambrian shield with old folding and faulting of the metamorphic rocks (gneiss). The majority of the region around NPD site

[2] Includes construction cost for railroad from CRL to Mattawa.

has been mapped as bedrock outcrop and the developed portion of the site is located where fluvial sand and gravel are the surficial material. At the WL site, the regional surficial geology comprises widespread deposits of till and glacio-fluvial and glaciolacustrine materials. The stratigraphic units in sequence from bedrock upwards are silty sand till, clayey silt till, silty clay and an upper soil complex comprised of laminated clayey silt with minor interbeds of massive silty clay and finally surface organics. Subsurface investigations on CRL property have concluded that the geology on-site is acceptable for the construction and operation of an ECM. Both WL and NPD locations may be geologically suitable sites for a NSDF. Although, geological studies would be needed to confirm the suitability of both the WL and NPD sites for a NSDF; it is expected that a facility could be constructed safety at both locations based on similar geology at the sites.

All three sites support a diverse mix of upland and wetland habitats. Vegetation on the CRL site includes deciduous and coniferous forest and a wide variety of plant species, including eight listed plant species. The NPD site is mainly wooded with the exception of open wetland areas. Wooded uplands generally range from 40 to 80 years old and wetlands are mainly found on the western half of the NPD site. The WL site is primarily under treed cover, consisting of a mixture of wetlands and forests of broadleaf, mixed and coniferous stand types. A large area contains a complex of bog, fen and swamp wetlands spanning the center and east portions of the WL site. The disturbance footprint of the NSDF would be similar for all sites, and similar mitigation would be implemented to reduce or limit effects to the terrestrial biodiversity. For example, the disturbance footprint would be designed to avoid wetlands and limit disturbance to the natural environment to the extent feasible.

Wildlife species found on the CRL and NPD sites are generally typical for a boreal region in Ontario. At the CRL site, a total of 24 species at risk have been confirmed including four species of turtle, four species of bats, several forest songbirds, eastern milk snake, western chorus frog, and Monarch butterfly. Nine species at risk have been confirmed on the overall NPD site including eastern small-footed myotis, little brown myotis, northern myotis, eastern milk snake, monarch butterfly, and several bird species, most notably the chimney swift. Over 50 species of mammals can be expected to be found around the WL site; many of the mammals are common and widespread. The Winnipeg River is an important migratory corridor for many bird species and there are important bird migration staging areas on, or near the WL site, centering on the Winnipeg River. Eight species at risk have been confirmed on the overall WL site, including little brown myotis, northern myotis, snapping turtle, and several bird species. Although the footprint for each alternative would be similar, the wildlife habitat potentially affected is different. A portion of the CRL property has identified critical habitat for Blanding's turtle, whereas there is no critical habitat identified by Environment and Climate Change Canada at WL or NPD sites. However, as mentioned above, the disturbance footprint would be designed to avoid wetlands and limit disturbance to the natural environment to the extent feasible. Other potential effects are similar between the alternatives and include short-term sensory effects of noise from blasting activities on bats and song birds, and increased injury and mortality to wildlife from traffic, particularly turtles. Mitigation to be implemented is standard at all CNL sites and includes implementation of a Blasting Plan and enforcement of reduced speed limits on-site, respectively.

The Ottawa River is the dominant drainage feature in the area for both the CRL and NPD sites, and all surface drainage on these sites ultimately drains to the river. The CRL and NPD sites are located in the Allumette Lake and Lac Coulonge reach of the Ottawa River, which extends approximately 90 km between La Passe and the Des Joachims Dam. The Ottawa River supports diverse warm-water and cool-water fish communities consisting of at least 55 documented species. Typical catches from the Ottawa River include walleye, northern pike, channel catfish, small mouth bass and lake sturgeon, channel catfish being the most abundant.

The provincially-rare fish species in the Ottawa River includes the American Eel, Lake Sturgeon, Northern Brook Lamprey and River Redhorse. Fish in inland lakes on the CRL site include pumpkinseed, northern pike, bass, and yellow perch. Minnow species such as shiner, dace and chub are abundant in streams and lakes on the CRL site. The Winnipeg River is the dominant drainage feature in the area and surface water run-off at the WL site drains into the Winnipeg River. The Winnipeg River supports a variety of forage fish species such as carp and other minnow species. Predator fish in the area include walleye, northern pike, smallmouth bass, mooneye and lake trout. The carmine shiner, listed as threatened under the *Species at Risk Act*, is likely to occur in the vicinity of WL site. Lake Sturgeon, with a status of Endangered under the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), is found in the Winnipeg River. No anticipated differences are anticipated between the alternatives as mitigation would be implemented to reduce or eliminate effects to aquatic diversity. For example, regardless of whether or not the facility is constructed and operated on-site or off-site, leachate from the ECM would be collected and treated via a WWTP prior to discharge to the receiving environment.

Shipping nearly 1,000,000 m^3 of waste from CRL to WL or the NPD site, at an average of 20 cubic metres per truck (m^3/truck) would result in 50,000 shipments. The potential environmental effects of transporting such large volumes by truck will be greater than disposal in an on-site facility at CRL. The off-site transport of large amounts of radioactive waste on public roads (i.e., 50,000 shipments travelling roughly 1,900 km from CRL to WL or 35 km from CRL to NDP) may raise perceived safety concerns amongst the public. In addition, the transportation of waste may result in increased pressure on the existing transportation infrastructure. The NSDF Project will create employment and business opportunities, regardless of where the facility is located; however, disposal of the waste at the WL or NPD site would result in a few more opportunities associated with the transportation of the waste off-site.

2.5.4.4 Summary

The comparative evaluation between facility location alternatives is provided in Table 2.5-4. The CRL property has the suitable geology and area needed for the safe construction and operation of a NSDF. Building a disposal facility on-site has the advantages of being closest to future decommissioning waste and legacy waste stored at CRL WMAs. The associated cost of transporting waste to a facility at CRL is considerably less than transporting the waste to a WL or NPD location. Moreover, the non-CRL options are more likely to raise public concerns related to transportation safety of larger volumes of wastes. Also, both WL and NPD are scheduled to be closed within the next decade, and therefore, will not have the services and management infrastructure required to safely and securely operate the NSDF. As such, WL and NPD off-site locations are less favourable.

Table 2.5-4: Evaluation of Alternatives – Facility Location

Criteria	Alternative 1 – On-site at CRL		Alternative 2 – Off-site at non-CRL sites	
Technical Feasibility				
Project Purpose	The NSDF satisfies the project purpose and allows for the planned accelerated decommissioning and site restoration activities, liabilities and the cost of laboratory operations to taxpayers in the 10-year period 2016 to 2025.		As closure is underway at WL and NPD and will be completed within the next decade, they are not considered technically feasible without continuation of the support services required.	
Schedule	Construction of the NSDF would be completed such that facility would be ready to accept waste in 2020.		Closure is underway at WL and NPD and will be completed within the next decade, and therefore do not meet the project schedule.	
Storage Capacity/Expandability	Both alternatives have sufficient area available to develop a facility with a storage capacity of 1,000,000 m^3.			
Proven Technology	Both alternatives would be using the same proven technology for the NSDF design.			
Design Robustness	Design requirements would be the same for a NSDF facility at CRL or off-site.			
Monitoring Complexity	Monitoring requirements would be the same for a NSDF facility at CRL or off-site.			
Economic Feasibility				
Lifecycle Costs	Total lifecycle costs are estimated to be \$600 M for a facility on the CRL site.		Additional geological studies would be needed to confirm the suitability of the off-site alternatives. Operations costs would also be much higher as a result of the packaging and transportation of waste off-site. Total lifecycle costs for disposal at WL site are estimated to be \$965 M (truck) \$12.4 M (rail).	(WL site) (NPD site)

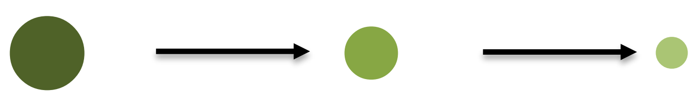
Table 2.5-4: Evaluation of Alternatives – Facility Location

Criteria	Alternative 1 – On-site at CRL		Alternative 2 – Off-site at non-CRL sites	
Environmental Effects				
Biophysical				
Atmospheric Environment	Decreased air emissions and greenhouse gases as most of the waste to be disposed in the NSDF is from the CRL site. Closest local resident is approximately 6 km way from the site.		Additional transportation of waste would result in increased air emissions and greenhouse gases. Nuisance noise effects have the potential to be greater given the close proximity of local residents.	
Geological and Hydrogeological Environment	Subsurface investigations on CRL property have concluded that the geology on-site is acceptable for the construction and operation of an ECM.		Geotechnical studies are required to confirm the suitability of the two off-site locations; however it is expected that a facility could be constructed safety at both locations based on similar geology at the sites.	
Surface Water Environment	No anticipated differences are anticipated between the alternatives; all three sites are located within close proximity to a major water feature (i.e., Winnipeg River or Ottawa River).			
Aquatic Biodiversity	No anticipated differences are anticipated between the alternatives.			
Terrestrial Biodiversity	Critical habitat for species at risk identified at CRL, whereas it is not at WL or NPD. However, the disturbance footprint would be designed to avoid wetlands and limit disturbance to the natural environment to the extent feasible.		No critical habitat for species at risk is present on the NPD or WL site.	(NPD site) (WL site)
Ecological Health	No anticipated differences are anticipated between the alternatives.			
Social				
Socio-economics	New employment and business opportunities associated with the NSDF Project.		The transportation of waste will result in a minor increase in employment and business	

Table 2.5-4: Evaluation of Alternatives – Facility Location

Criteria	Alternative 1 – On-site at CRL		Alternative 2 – Off-site at non-CRL sites	
			opportunities; however, additional haul truck traffic may also increase pressure on the existing transportation infrastructure.	
Land and Resource Use	No anticipated differences are anticipated between the alternatives.			
Human Health and Safety				
Public Health & Safety (construction and operations)	No off-site transportation of waste is required.		The off-site transport of large amounts of radioactive waste on public roads may raise perceived safety concerns amongst the public	
Public Health & Safety (long-term)	Both alternatives can be developed in a manner that protects public health and safety in the long-term.			
Worker Health & Safety	Both alternatives can be developed in a manner that protects worker health and safety.			

Notes:



Most Favorable Favorable Least Favorable

2.5.5 Site Selection

The selection process for the siting of the NSDF at CRL began with the establishment of mandatory criteria that must be satisfied by candidate locations; mandatory criteria included minimum area of 30 ha, minimum site width of 200 m, access to water for sanitary and process requirements, access to electrical power, and access to gas or other heating fuel (CNL 2016a). Exclusion criteria was then applied to remove any locations that were constrained by project requirements or by pre-defined factors; exclusion criteria are physical, cultural, and biological features that will eliminate a location from the list of potential sites because development is either not permitted or poses a risk for the intended use/project (CNL 2016a). The site remaining were evaluated in terms of rated comparison criteria, and included considered feedback received during engagement activities.

Two candidate locations were identified for siting the NSDF after application of the mandatory attribute criteria and the exclusion criteria; 1) the East Mattawa Road site (EMR site); and 2) the Alternate site. The locations of the two sites are shown on Figure 2.5.5-1 and described below. When evaluating the technical feasibility of the facility location, many of the criterion can be satisfied by both alternatives. For example, both alternatives can be constructed such that they meet the purpose of the project and the required project start date (i.e., 2020). In addition, both alternatives can be constructed to accommodate 1,000,000 m^3 of LLW and both allow for future expandability, if required. Key differences in the alternatives are primarily related to monitoring complexity, lifecycle costs and potential environmental effects; as such, the evaluation focuses on these criterion.

2.5.5.1 East Mattawa Road

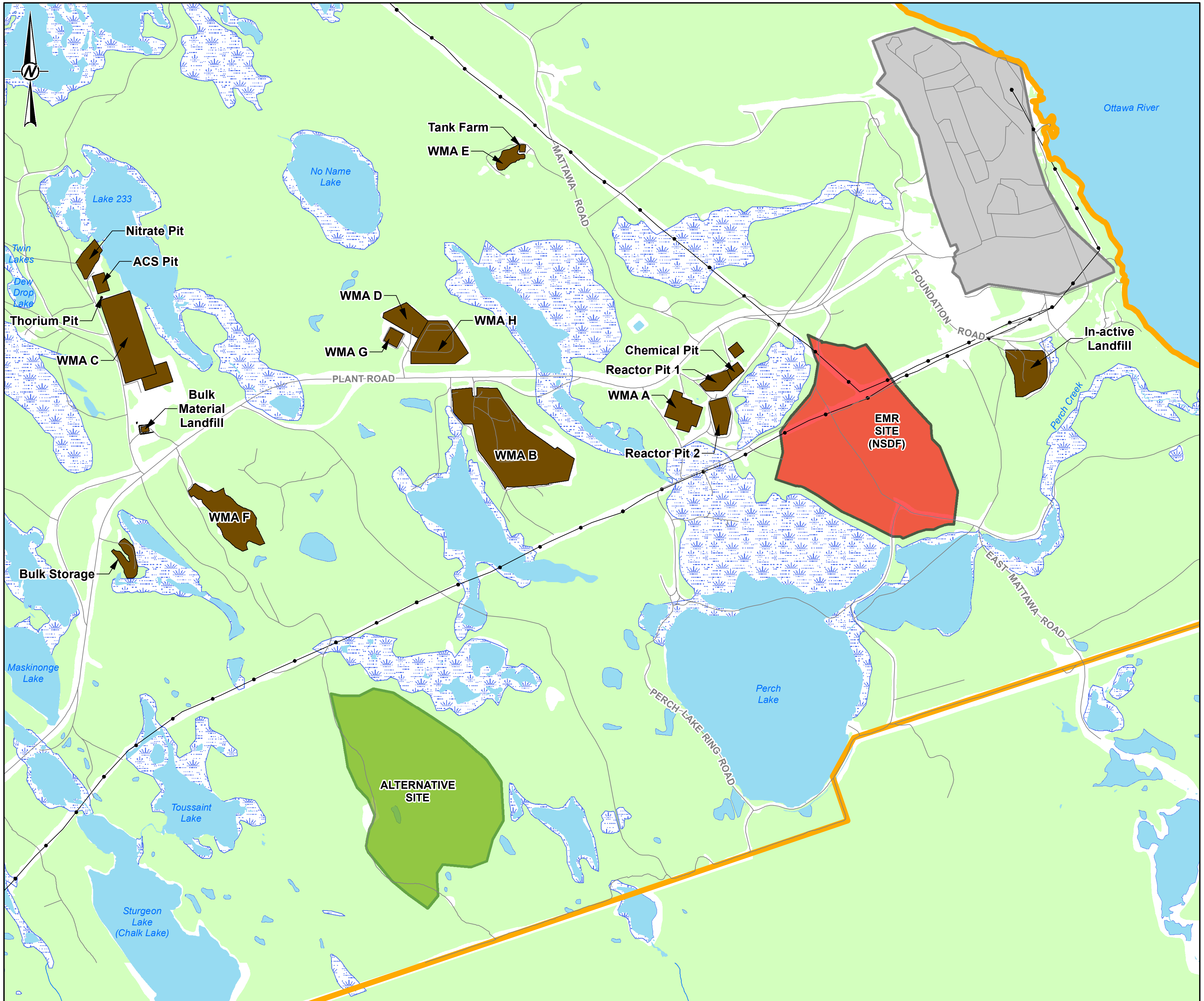
2.5.5.1.1 Technical Feasibility

In general terms the EMR site is located either side of the existing East Mattawa Road that bisects the site crossing north to south and is approximately 34 ha in size (Figure 2.5.5-1). The northern boundary abuts Power Line Road and the southern boundary is just short of Dump Road and the Perch Lake Ring Road. On the western side, a 30 m setback from the Perch Lake wetlands forms the site boundary and to the west a local ridge line of the Ottawa Valley and the Perch Lake and Perch Creek water sheds form the boundary. The site boundary to the north is forested land between the hydro corridor and Plant Road. To the west and south is a low lying marsh area, with existing Waste Management Area A and B further northwest. The South East Mattawa Road leads to Dump Road and the Perch Lake Ring Road. To the east is forested land, which drops down to the main CRL site on the opposite side of the ridge.

The East Mattawa Road is one of three existing designated emergency evacuation routes from the CRL Main Campus. Access to the site is provided by both the Dump Road and the Emergency Road #3. Both access routes are regularly travelled and subject to routine maintenance. Emergency Route #3 is being re-routed as part of a previously planned upgrade to this road. Overall, access to the EMR site is well established and upgrades required for heavy equipment and truck traffic to the NSDF would be minimal.

Mandatory services (i.e., Class IV power, water for sanitary and process requirements, gas or other heating sources) can be readily accessed from the EMR site. The EMR site is approximately 500 m from the CRL Main Campus, which is the source of CRL's decommissioning work that will generate much of the waste. Overall, the services required to support the NSDF Project are all located much more proximate to the EMR site. A potential water source could be taken from 500 m from the EMR site, and a natural gas pipeline is installed along Plant Road at the juncture of EMR site. There is the possibility of other projects being developed in this area that may also reduce some of the costs associated with construction of the NSDF by combining efforts.

This page intentionally left blank



LEGEND

- ROADS
- RAILWAY
- TRANSMISSION LINE
- RIVER/STREAM
- WATERBODY
- WETLAND
- WOODED AREA
- EAST MATTAWA ROAD (EMR) SITE
- ALTERNATE SITE
- CRL MAIN CAMPUS
- CRL PROPERTY
- WASTE MANAGEMENT AREA (WMA) [1]

500 0 500

1:15,000 METRES

NOTE(S)

1. LIQUID DISPERSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.

REFERENCE(S)

1. BASEDATA ONTARIO MNRF 2016, CANVEC 2016, AND CNL 2016
2. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
3. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
SITE OPTIONS EVALUATED FOR THE NEAR SURFACE DISPOSAL FACILITY PROJECT

CONSULTANT

Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	MM
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0001	0.0	2.5.5-1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm

This page intentionally left blank

The EMR site is located within the Perch Lake drainage basin, which has been impacted by plumes emanating from the WMA A and the Liquid Dispersal Areas. As such, extensive environmental studies have been completed and continue to be ongoing as part of CNL's existing Environmental Management Plan. The Environmental Management Plan for the CRL property can easily be expanded to include monitoring and sampling locations for the NSDF.

2.5.5.1.2 Economic Feasibility

Both site areas' overburden is adequate and site clearing costs will be comparable between the sites as tree growth density characteristics are similar. Although most of the area within the EMR site is flat; there is a potential of having to move the 115 kilovolt (kV) transmission lines that are located within the footprint for the Phase 2 expansion to 1,000,000 m³ waste volume; this would increase site preparation costs for the EMR site. It is estimated that the relocation of the 115 kV transmission lines would be at a cost of $3 to 6 M.

Overall, the services required to support the NSDF are all located much more proximate to the EMR site. A potential water source could be taken from 500 m from the EMR site, and a natural gas pipeline is installed along Plant Road at the juncture of EMR. There is the possibility of other projects being developed in this area that may also reduce some of the costs associated with construction of the NSDF by combining efforts.

Extensive environmental studies have been completed and continue to be ongoing as part of CNL's existing Environmental Management Plan in the vicinity of the EMR site. Existing monitoring and sampling locations are also applicable for the NSDF Project and the Plan can easily be expanded to include additional monitoring and sampling locations for the NSDF Project, if required.

2.5.5.2 Alternate Site

2.5.5.2.1 Technical Feasibility

The Alternate site is located southeast of WMA F (Figure 2.5.5-1) and is approximately 34 ha in size. Access to the Alternate site is via the existing Port Hope Road, a narrow gravel road adjacent to the western border of the site. The existing access road to the site from the Plant Road is 2.2 km long and will require considerable upgrades to provide safe passage of heavy equipment and tractor trailer traffic. Electricity is available from along the Plant Road, as well as natural gas from the pipeline recently installed on the CRL property, but are approximately 2.2 km from the Alternate site. Water service is available at the CNL Main Campus, but a new feed will be needed. The proposed tie-in to the water supply will be approximately 5 km from the Alternate site and a pipeline and pumping station would be needed to deliver water uphill to the facility. Additional space is available to the area to the north of WMA F for use as a trainer/lay down areas (currently used to store marine containers) or future facility expansion. Space is also available south of the Alternate site, close to the border with Garrison Petawawa.

The Alternate site is located in a Greenfield area. As such, extensive modifications to CNL's existing Environmental Management Plan are needed to include monitoring and sampling locations for the NSDF Project.

2.5.5.2.2 Economic Feasibility

As previously mentioned, both site areas' overburden is adequate and site clearing costs will be comparable between the sites as tree growth density characteristics are similar. However, if portions of the Alternate site area with >10% slopes are required to be used, it will result in increased site preparation costs. There are no

plans to develop other projects at this location; therefore, there is no opportunity to reduce the cost of the NSDF by sharing costs with other projects. The Alternate site will require considerable road upgrades for the 2.2 km route from the Plant Road to provide safe passage of heavy equipment and tractor trailer traffic. Electricity, natural gas and water supply would need to be brought in from a further away source. Overall, infrastructure costs are higher for the Alternate site as compared to the EMR site. In addition, monitoring costs would be higher as the existing CNL Environmental Management Plan does not include current monitoring and sampling locations at the Alternate site.

2.5.5.3 Environmental Effects

The EMR Site is located within the Perch Lake drainage basin, which has been impacted by plumes emanating from the WMA A and the Liquid Dispersal Areas. Extensive environmental studies have been completed in the Perch Lake wetland complex, located to the west of the EMR Site, to characterize the existing radiological contamination in the soil and vegetation. Of particular interest is the legacy waste site a WMA A, which discharges contaminated groundwater into the associated Perch Lake wetlands creating a brownfield. The EMR site is in closer proximity to existing brownfield waste sites, and as such, consolidates waste land uses. The Chalk Lake Basin, within which the Alternative site is located, contains no operating facilities, WMAs, or any known contamination, and is therefore unaffected by CRL activities. The WMA F is the nearest waste management area located approximately 1.5 km the north of the Alternate site, in the Maskinonge Lake basin. The Alternate site is in a Greenfield area. There are no pre-existing plumes or contamination from WMAs in the vicinity of the Alternate site, thus introducing a new WMA which is not contiguous with current CRL brownfield areas or impacted areas.

The EMR site is close to the CRL Main Campus, which is where the vast majority of new waste from building decommissioning will be generated. The EMR is approximately 4 km closer the CRL Main Campus as compared to the Alternate site; trucks will travel approximately 6 to 7 km for delivering waste to the Alternate site from the CRL Main Campus. The increased transportation distance of wastes to the Alternate site would result in increased air emissions, and therefore greenhouse gases. Any dust created from the NSDF construction and operation on either site would be abated as per environmental protocols. Noise transmission to the CRL Main Campus will be mitigated by the topography as the EMR site is situated on the lower side of the hill between Foundation Road and Emergency Route #3. The Alternate site would not be visible to traffic on Plant Road or at the CRL Main Campus; noise is not anticipated to be an issue as the area is isolated.

In 2016, geotechnical surveys were completed at the EMR site (Golder 2016). Ground surface elevations range at the EMR site from a low of approximately 160 metres above sea level (masl) within the low-lying and relatively flat terrain bordering the north side of Perch Lake, to a high of 196 masl along the crest of the ridge to the east of Emergency Road #3 that separates the Perch Lake and Ottawa River drainage basins. The overburden thickness at the site typically ranges from approximately 0 to 10 m, depending on bedrock topography. The surficial geology consists primarily of sands, underlain by dense sandy silt till which contains some cobbles and occasional boulders. Organic soils (e.g., peat) have been deposited in the low-lying and wetland areas.

Precipitation in the EMR site area recharges a shallow groundwater system that includes the overburden and the upper few metres of fractured bedrock. Groundwater levels range from about 0.5 m to more than 11.4 m depth, corresponding to elevations of between approximately 173 and 158 masl. Groundwater flow directions reflect the site topography with the overall direction being southwesterly from the ridge bounding the east side of the site and semi-radial from elevated lands within the bedrock bench. Within the low saturated lands to the west of

the siting block, groundwater flow parallels the Perch Lake surface drainage. The crest of the ridge along the eastern side of the siting block is interpreted to roughly coincide with a groundwater (and surface water) divide between the Perch Lake basin and the Ottawa River.

The EMR site is located in the Perch Lake basin and drains via Perch Lake and Perch Creek to the Ottawa River. The distance from the center of the EMR Site to the closest point on the Ottawa River is approximately 1.1 km. Groundwater transit times between the southwestern boundary of the EMR site and Perch Creek are calculated to be between 10 and 12 years. The transit time from discharge to Perch Creek to the Ottawa River is negligible yielding a combined groundwater/surface water transit time for the flow path from the EMR site to the Ottawa River of 10 to 12 years. Groundwater transit times for most radionuclides will be substantially longer due to sorption onto the soil matrix.

In 2014, geotechnical surveys were completed at the Alternate site (Golder 2016 [referred to as Block 11 in the report]). The Alternate site is reflective of the CRL site as a whole. The overburden thickness ranges from approximately 0 to 20 m depending on the bedrock topography. Generally, the overburden contains a thin layer of organic topsoil at the surface with a layer of loose sand, then compacted sand. The site is characterized by an undulating ground surface ranging from approximately 172 masl in the east and northeast to a low of approximately 115 masl in the wetland areas bordering Chalk (Sturgeon) Lake, which is located roughly 600 m to the southwest. Overall, the ground surface slopes to the west.

Precipitation falling on topographically high areas results in the recharge of the shallow-scale groundwater system that includes the overburden and the upper few metres of fractured bedrock. Groundwater levels beneath the Alternate site range from about 0.5 m to more than 9 m depth, corresponding to elevations of between roughly 164 and 150 masl. The southwestern part of the Alternate site is well drained, but much of the central portion of the area is low-lying terrain resulting in with seasonal accumulations of surface water and saturated ground.

The Alternate site is located in the Chalk Lake Basin and lies between Toussaint Lake on the west and Perch Lake on the east, close to the south boundary of the CRL property. Toussaint Lake drains by a small stream to Chalk (Sturgeon) Lake which in turn drains to the Ottawa River. The aerial distance from the center of the Alternate site to the closest point on the Ottawa River is approximately 3.3 km. Groundwater flow within the site is in a southwesterly direction toward Toussaint Lake to Chalk Lake and all runoff at the site ultimately discharges to the Ottawa River either as surface water flow or groundwater seepage. The groundwater transit time through the groundwater flow system between the centre of the Alternate site to the Toussaint Lake is estimated to be two years. Once in Toussaint Lake, any groundwater that has come to surface could take as little as four months to travel to Chalk Lake. It is estimated that a combination of surface water and groundwater could reach the Ottawa River in less than three years. Therefore, the groundwater transit time to the closest surface water body is shorter from the Alternate site although the EMR site is closer to the Ottawa River. At either location, the facility will be designed to be protective of the environment.

The EMR site is similar to the majority of the undisturbed forested areas of the CRL property in terms of terrestrial biodiversity. In the spring and summer of 2016, a biodiversity study was completed at both the EMR site and Alternate site. No butternut trees were found within the EMR site or in the surrounding area during the biodiversity surveys. Several bird species, including Eastern Whip-poor-will, Eastern Wood-pewee, Wood Thrush, Golden-winged warbler and the Canada warbler were observed in the vicinity of the EMR site. Four bat

species were also detected including the Little Brown Myotis, Northern Myotis, the Tri-coloured bat and Eastern Small-footed Myotis.

Extensive environmental studies have been completed in the Perch Lake wetland complex (located to the west of the EMR site) to characterize the existing radiological contamination in the soil and vegetation. These wetlands are home to Blanding's and Snapping turtles. Biodiversity studies to date by CNL do not indicate that Blanding's turtles are making extensive overland movement in this area during their migration as no individuals have been sighted on the road in this location. Although the EMR site does not appear to fragment the Blanding's turtle habitat, development at the EMR site may encroach on some portion of the species terrestrial habitat. The EMR site is located immediately adjacent to the Perch Lake wetland and, therefore, has an increased potential for indirect effects on terrestrial species that use this habitat.

The Alternate site is similar to the majority of the undisturbed portion of CRL property in terms of terrestrial biodiversity. Several songbirds were observed during the 2016 biodiversity surveys including Canada Warbler, Eastern Wood-pewee and Eastern Whip-poor-will. Bat surveys confirmed the presence of Little Brown Myotis, Northern Myotis, and the Tri-coloured Bat and Eastern Small-footed Myotis. Blanding's turtles have been observed using the adjacent wetlands habitat and crossing Port Hope Road during their spring migration. The Alternate site encroaches on the Blanding's turtles travelling corridor within the CRL property, which would potentially cause a slight fragmentation between habitats and may increase the potential for road mortality. No Butternut trees were observed during the biodiversity surveys.

Similar mitigation for both site locations would be required to limit effects to terrestrial biodiversity. These mitigation include the protection of migration pathways for Blanding's turtles, installation of bat boxes, tree removal before and after the migratory bird nesting period and environmental awareness training for Contractor personnel. In addition, erosion and sediment control practices (e.g., silt fences, runoff management) already in place at the CNL property will be used during construction around disturbed areas, and existing programs such as CNL's Management of Land and Habitat Procedure will be implemented.

There are six archaeological sites previously recorded within 1 km of EMR site, but none are located directly within the proposed footprint. An archaeological assessment was completed at the EMR Site in 2016 to identify cultural resources, determine their significance and identify any mitigation that may be required. Test pits were excavated during Stage 2 and 3 archaeological assessment. As a result of these archaeological assessment, modifications to the Project footprint were made to avoid a homestead. Following Stage 2 and Stage 3 excavations, two locations were identified for management of artefacts (i.e., Stage 4 assessment). An archaeological assessment was completed for the Alternate site in 2013 and 2014 and results indicate that there are no significant cultural resources within the areas surveyed.

In 2008, CNL developed an Archaeological Master Plan that resulted in a formal Cultural Resource Management (CRM) program at CNL. The CRM program is used to identify unanticipated archaeological resources and implement adaptive management (e.g., footprint can be modified so that archaeological sites identified will not be affected). If during site preparation or construction activities, cultural material is identified, activities will be stopped and the CNL Cultural Resource Management specialist will be contacted.

Both alternatives would implement mitigation that provides for worker and public health and safety during all phases of the NSDF Project. In addition, mitigation implemented to protect the surface water environment, aquatic biodiversity and ecological health would be similar for both sites. Employment and business opportunities, and community well-being would also be similar for both site locations.

2.5.5.4 Summary

The comparative evaluation between facility location alternatives within the CRL property is provided in Table 2.5-5. As shown in the table, the EMR site is preferable for both economic and environmental reasons. In summary, the EMR site is adjacent to a Legacy Waste Management Area and in closer proximity to the exiting waste operational areas. This represents a tighter consolidation of waste uses and less effects on Greenfield areas. In addition, the Perch Lake drainage basin has been impacted by plumes emanating from the WMA A and the Liquid Dispersal Areas. Conversely, development of the Alternate site would involve the consumption of Greenfield lands for waste uses and would establish a new waste area not contiguous with existing waste/brownfield areas. In addition, comments received from the public on the NSDF Project to date, indicate a preference for the EMR site due as it is located within a brownfield area. There may be perceived increased risks of the EMR site as it is located closer to the Ottawa River; however, the groundwater transit time from the EMR site to nearest surface water body is estimated to be 12 to 35 years compared to approximately two years for the Alternate site.

Table 2.5-5: Evaluation of Alternatives – Site Selection

Criteria	Alternative 1 – EMR Site		Alternative 2 – Alternate Site	
Technical Feasibility				
Project Purpose	Both sites are technically feasible.			
Schedule	Both alternatives could be constructed to meet the Project start date.			
Storage Capacity/Expandability	Both alternatives have sufficient area available to develop a facility with a storage capacity of 1,000,000 m^3.			
Monitoring Complexity	Extensive monitoring programs already exist in the vicinity of the EMR site; therefore, the existing Environmental Monitoring Plan for the CRL property can easily be expanded to include monitoring and sampling locations for the NSDF Project.		Modifications to CNL's existing Environmental Monitoring Plan are needed to include monitoring and sampling locations for the NSDF Project.	
Economic Feasibility				
Lifecycle Costs	There is potential for some cost savings by sharing services with other projects and the EMR site.		There would be increased costs in extending services, including new roads, at the Alternate site and there is no opportunity to reduce the cost of the NSDF by sharing costs with other projects. In addition, there would be increased operational costs related to transporting waste to the site.	
Environmental Effects				
Biophysical				
Environmental Setting	The EMR site is located in the Perch Lake basin, which has been impacted by plumes emanating from the WMA A and the Liquid Dispersal Areas (i.e., brownfield site) and as such, consolidates waste land uses.		The Alternate site is located in the Chalk Lake basin, which is an undisturbed area with no previous contamination (i.e., Greenfield site).	
Atmospheric Environment	The EMR is approximately 4 km closer the CRL Main Campus as compared to the Alternate site.		The increased transportation distance of wastes to the Alternate site would result in increased air emissions, and therefore greenhouse gases.	

Table 2.5-5: Evaluation of Alternatives – Site Selection

Criteria	Alternative 1 – EMR Site		Alternative 2 – Alternate Site	
Geological and Hydrogeological Environment	The groundwater transit time from the EMR site to nearest surface water body is estimated to be 12 to 35 years		The groundwater transit time from the Alternate site to nearest surface water body is estimated to be two years	
Surface Water Environment	No anticipated difference between alternatives.			
Aquatic Biodiversity	No anticipated difference between alternatives.			
Terrestrial Biodiversity	The site is located immediately adjacent to the Perch Lake wetland, and therefore has an increased potential for indirect effects on terrestrial species that use this habitat.		The Alternate site encroaches on the Blanding's turtles travelling corridor within the CRL property, which would potentially cause a slight fragmentation between habitats and increases the potential for increased road mortality.	
Ecological Health	No anticipated difference between alternatives.			
Social				
Socio-economics	No anticipated difference between alternatives.			
Land and Resource Use	There are six archaeological sites previously recorded within 1 km of EMR site, but none are located directly within the proposed footprint.		An archaeological assessment was previously completed and results indicate that there are no significant cultural resources within the areas surveyed.	
Human Health and Safety				
Public Health & Safety (construction and operations)	Both alternatives can be developed in a manner that protects public health and safety during construction and operations.			
Public Health & Safety (long-term)	Both alternatives can be developed in a manner that protects public health and safety in the long-term.			
Worker Health & Safety	Both alternatives can be developed in a manner that protects worker health and safety.			

Notes:

2.5.6 Leachate Treatment

Leachate is generated as water infiltrates through the ECM during operations (and to a lesser extent during the post-closure phase). The maximum average annual wastewater volume to be produced during operations is predicted to be 6,556 m^3/year. Another important hydraulic consideration is the maximum wastewater flow rate that must be received and processed by the WWTP. Leachate and decontamination water are produced at relatively low rates compared to contact storm water, especially during major storm events. The maximum hydraulic flow rate was determined by back-to-back 100-year, 24-hour storm events (2,820 m^3) and was selected as a worst-case design condition for determining the required volume of wastewater to be treated. Effluent from the WWTP will be discharged to an infiltration pit. A comparison of projected leachate concentrations and discharge requirements shows that several radionuclides and non-radionuclides may be present at concentrations in the wastewater that exceed discharge requirements, and treatment for these designated contaminates of potential concern (COPC) will be required. The WWTP must therefore be designed for removal of radionuclides and heavy metals. Three alternative means of leachate treatment were considered for meeting the above mentioned design requirements for the NSDF Project: 1) construction of a new WWTP; 2) use of the existing waste treatment centre; and 3) construction of a leachate evaporation pond.

2.5.6.1 Waste Water Treatment Plant (New)

A new WWTP is proposed that will be used for treatment of wastewater sources at the NSDF site, including contact storm water and leachate generated from the ECM, equipment and personnel decontamination water, and laboratory wastewater. The operating period of the NSDF is 2020 to 2070, and wastewater treatment is required for the full duration of operations and plus several years following closure of the ECM and installation of the final cover. The proposal to build a new, stand-alone treatment plant would use the best demonstrated available technology that is economically achievable (BATEA) for removal of the COPC from the NSDF wastewater.

Treatment processes were selected based on the projected wastewater quantity and characteristics, results of laboratory scale testing and the ongoing pilot scale test, an assessment of the treatability of the NSDF wastewater, and the results of optioneering studies, which determined BATEA and provided the foundation for the Design Concept Decision. The expected performance of the major treatment processes was determined from the results of the laboratory scale tests and ongoing pilot scale test, and this data was used to determine removal efficiencies for COPC in the wastewater simulant, as well as characteristics of intermediate process wastewater streams and outputs.

A new WWTP is the most favourable option as it is technically feasible, and will be designed to optimize environmental protection in a cost-effective manner while meeting regulatory requirements. The WWTP includes two duplicate trains of treatment, and is made up of the following primary components: influent equalization, chemical precipitation, clarification, membrane filtration, ion exchange, final effluent storage, residuals storage and dewatering, and support facilities. This also includes confirming that the treated leachate is returned to the Perch Lake watershed in a manner that reduces effects on the watershed and local biota (analogous to small scale pump and treat operations currently in service at CNL).

Options for discharge of the treated effluent are:

- discharge by pipe directly to surface water bodies in the Perch Lake Wetland such as Perch Lake, Perch Creek or discharge to the Ottawa River; and,
- discharge to ground within the NSDF footprint

Direct discharge by pipe to surface water bodies would require construction of a pipeline through potentially contaminated areas and potential disturbance of wetlands that support critical habitat for designated species-at-risk. Discharge of treated effluent to surface water bodies would not return water to the wetlands adjacent to the NSDF site.

Discharge of treated effluent to ground within the NSDF footprint would entail construction of an exfiltration gallery. The proposed location for the gallery is near the northern perimeter of the NSDF site. The treated effluent, once discharged to ground, would be returned to the Perch Lake Wetlands and discharge to a local stream. The estimated annual volume of the treated effluent to be discharged is 6,560 m^3.

2.5.6.2 Waste Treatment Centre (Existing Facility)

The existing Waste Treatment Centre (WTC) was built more than 40 years ago to treat low level radioactive liquid waste originating from reactor and site operations. The WTC is expected to reach its end life by 2024 and will not be available for the operating life of the NSDF (i.e., 2020 to 2070). In addition, although WTC nominally has the capacity to treat the volume of leachate predicted to be generated, this kind of throughput would pose a reliability risk to NSDF operations even if there were reinvestment in WTC. Overland transfer by tanker truck for the expected leachate volumes is not considered to be practical. An underground pipeline to bridge the 2 km distance between facilities would be required. The 2 km pipeline distance is longer than the distance to discharge points for the WWTP; and therefore more costly. It is also not certain that WTC decontamination performance is sufficient to meet treated leachate discharge/infiltration requirements, and therefore WTC may not be fit for purpose. The WTC operations are labour and energy intensive ($7M annually for the required throughput, exclusive of capital reinvestment). The WTC depends on powerhouse support (steam, steam condensate return in particular), and the powerhouse is slated for shutdown prior to 2025. For these reasons, the existing waste treatment facility is not a technically feasible option and is not further evaluated.

2.5.6.3 Leachate Evaporation Pond

Evaporation ponds are artificial ponds with very large surface areas that are designed to efficiently evaporate water by sunlight and exposure to the ambient temperatures. Leachate evaporation ponds are used in hot dry climates and are not effective in the mid-continental climate of central Canada with no distinct dry season. Therefore, a leachate evaporation pond is not considered to be a technically feasible alternative and is not further evaluated.

2.5.6.4 Summary

The new WWTP is the only technically feasible option available to treat the leachate to be generated from the NSDF. The WTC is expected to reach its end life by 2024 and will not be available for the operating life of the NSDF (i.e., 2020 to 2070), it is also not certain that WTC decontamination performance is sufficient to meet treated leachate discharge/infiltration requirements. Leachate evaporation ponds are used in hot dry climates and are not effective in the mid-continental climate of central Canada with no distinct dry season. As there is

only one technical feasible alternative, potential environmental effects on VCs are not presented in this section; rather the potential environmental effects of the new WWTP are evaluated in the EIS.

2.6 Conclusion

The recommended alternative for the disposal of low-level waste based on the Alternative Means analysis is to build a NSDF at the CRL property on the ERM site. The preferred design is that of an ECM along with a WWTP for leachate treatment. The most favourable alternative means are based upon consideration of economic, environmental and technical factors.

3.0 PROJECT DESCRIPTION

3.1 Introduction

This section provides a description of the main features of the Near Surface Disposal Facility (NSDF) Project, the Integrated Waste Strategy (IWS) to be implemented for the NSDF Project, and identifies the works and activities related to the construction (which includes site preparation), operations, closure, and post-closure phases. Details of the NSDF Project will continue to evolve and be modified during future stages of its design. At its present stage, however, the design represents a reasonable implementation scenario that is based on current engineering practice and precedents, and the experience of the engineering and environmental assessment teams. Where there remains uncertainty around the design, conservative assumptions or options still under consideration have been presented herein to provide a conservative assessment of potential effects of the NSDF Project in the environmental assessment.

3.1.1 Project Overview

The NSDF Project includes components and activities related to construction, operations, closure, and post-closure, as well as long-term performance of the engineered containment mound (ECM) for the management of radioactive waste and mixed waste that meet the Waste Acceptance Criteria (WAC).

The NSDF Project has been designed as a permanent disposal facility and incorporates proven technologies and best industry practices, including documented experience from the International Atomic Energy Agency (IAEA) and other similar national and international facilities (Section 2.4). The design life for the ECM is 500 years, which correlates to design lifespan criteria for similar mounds containing radioactive and mixed wastes in Canada (e.g., Port Hope and Port Granby Long-Term Waste Management Facilities).

The NSDF Project will have a total waste capacity of 1,000,000 cubic metres (m^3). The development of the facility and the placement of waste within the ECM will be completed in two stages. The first stage will have a total capacity of 525,000 m^3 and will accommodate wastes currently in storage and wastes to be generated over the next 20 to 25 years. The second stage will expand the facility by 475,000 m^3 (total of 1,000,000 m^3) of wastes to be generated until 2070.

The schedule for the NSDF Project is as follows:

- Construction Phase = 2018 to 2020;
- Operations Phase = 2020 to 2070;
- Closure Phase = 2070 to 2100;
- Post-closure Phase, with two discrete periods:
  - Institutional Control Period = 2100 to 2400; and,
  - Post-Institutional Control Period = 2400 plus.

The footprint of the NSDF Project site is approximately 34 hectares (ha). The main physical works related to the NSDF Project are the ECM that will contain the radioactive and mixed waste that meets the WAC; the wastewater treatment plant (WWTP) that treats leachate, contact water and operational waste water; various support facilities

that enable operation; and site infrastructure. All physical works are located within the NSDF Project site, which is located entirely within the CRL property (Figure 3.1.1-1).

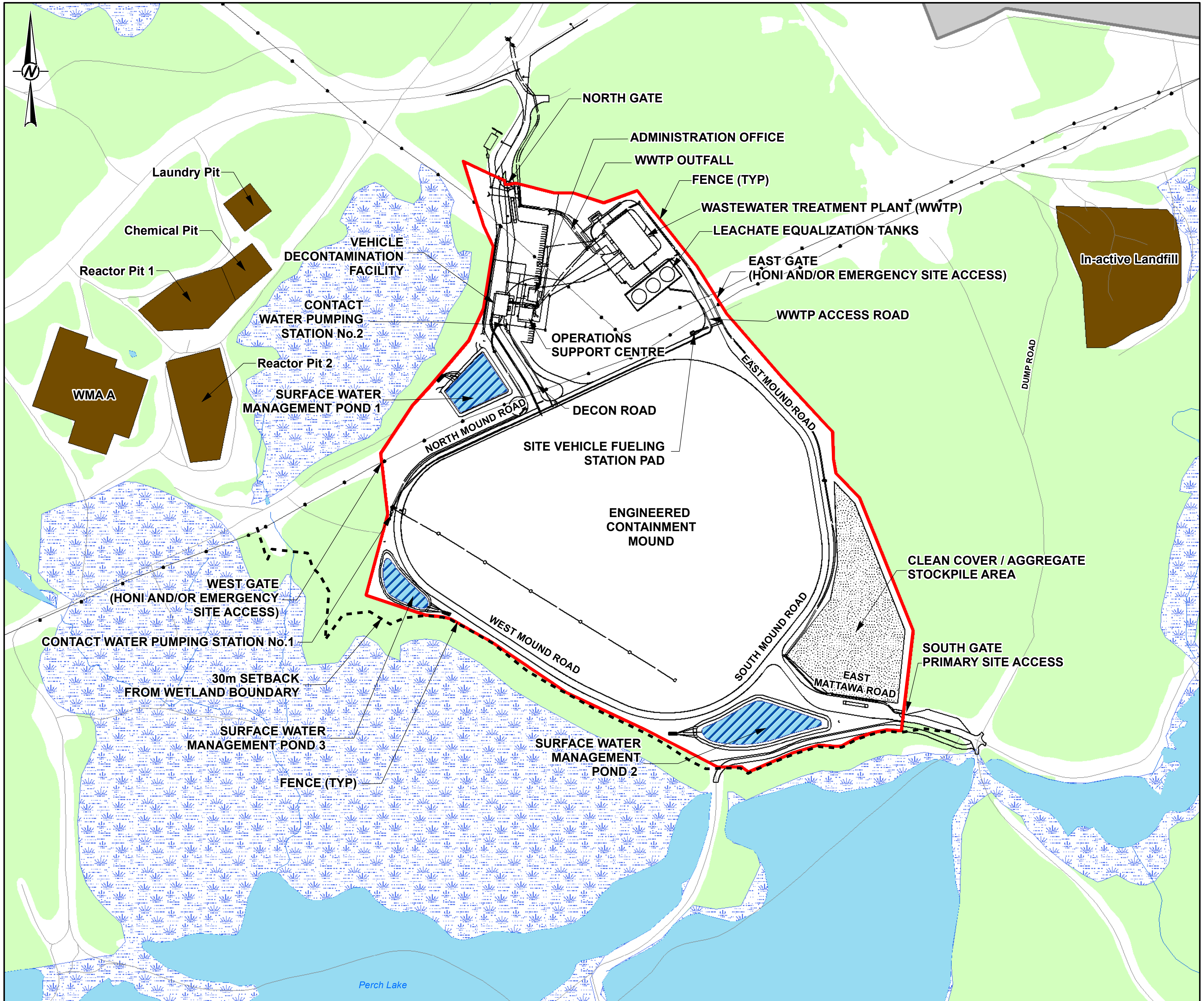
Canadian Nuclear Laboratories (CNL) aims to have the ECM operational in 2020. All site preparation activities will be completed, including vegetation clearing and earthworks, followed by the construction of the ECM and supporting infrastructure. The construction phase, which includes site preparation, is anticipated to start in 2018 pending the receipt of a positive environmental assessment decision. Construction activities are expected to take approximately two years to complete (i.e., by 2020).

The main components and activities associated with the construction phase of the NSDF Project include the following:

- transportation of construction materials;
- ECM liner construction, including construction of the berm;
- development of surface water management structures (i.e., drainage ditches, culverts, ponds);
- management of surface water during construction;
- management of construction wastes;
- construction and inactive commissioning of the WWTP;
- on-site road and access development;
- construction of support facilities (i.e., administration offices, operations support centre, vehicle decontamination facility, kiosks and vehicle weigh scales, and site vehicle refueling station); and,
- construction of site infrastructure (i.e., service elements [potable water, fire water, contact water leachate transfer system, electrical power, communications, natural gas, and sanitary sewage] and support elements [parking lots, site perimeter fencing and gates, laydown and stockpile areas, outflow for treated WWTP effluent]).

The operations phase is anticipated to begin in 2020, following construction, and will end in approximately 2070 (i.e., operating site life of 50 years). Waste to be placed in the ECM will primarily originate from operations and decommissioning activities at the CRL property, including legacy radioactive wastes currently stored on site, those from future operations, those which will be generated from the demolition and decommissioning of structures at CRL, and the remediation of some contaminated areas at CRL through to 2070. A few percent of the waste volumes to be placed in the ECM will be from off-site sources (e.g., Whiteshell Laboratories, commercial sources such as hospitals and universities).

232-509220-REPT-004
UNRESTRICTED



LEGEND

- ROAD
- TRANSMISSION LINE
- RIVER/STREAM
- WATERBODY
- WETLAND
- WOODED AREA
- CRL MAIN CAMPUS
- NSDF PROJECT SITE
- WASTE MANAGEMENT AREA (WMA)[1]
- SURFACE WATER MANAGEMENT POND
- STOCKPILE AREA

100 0 100 200
1:5,000 METRES

NOTE(S)
1. LIQUID DISPOSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.

REFERENCE(S)
1. BASEDATA ONTARIO MNRF 2016, CANVEC 2016, AND CNL 2016
2. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (NOVEMBER 2016)
3. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE18N

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
NEAR SURFACE DISPOSAL FACILITY SITE LAYOUT

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	MM
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0004	0.0	3.1.1-1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm

S:\Clients\Canadian_Nuclear_Laboratories\NSDF\99_PROJ\1547525_NSDF_EIS\40_PROD\0004_EIS_Section_3\1547525-0004-G-0001.mxd

This page left intentionally blank

The main components and activities associated with the operations phase of the NSDF Project include the following:

- staged development of disposal cells;
- receipt of radioactive waste and other wastes that meet the WAC;
- placement of radioactive waste and other wastes that meet the WAC in the ECM;
- progressive closure of disposal cells and installation of cover;
- expansion of CNL's Groundwater Monitoring Program to include the NSDF Project site;
- operation of the WWTP and discharge of treated effluent;
- surface water management and erosion control;
- domestic waste management;
- petroleum storage and hazardous materials handling; and,
- maintenance of infrastructure, facilities, and site services.

Activities associated with the closure phase primarily includes those activities necessary to complete the installation of final cover of the ECM and establish long-term monitoring systems. Closure activities are expected to start in 2070 and continue through to 2100, after which the NSDF Project will transfer into the post-closure phase. Most activities would be completed within the initial years of the closure phase, with the continued operation of the WWTP and performance monitoring through to 2100. Specifically, closure activities include:

- installation of the final cover of the ECM;
- restoration and grading of the NSDF Project site;
- continued operation of the WWTP and discharge of effluent; and,
- ongoing long-term performance monitoring.

The post-closure phase has two discrete periods: Institutional Control and post-Institutional Control. The Institutional Control period includes implementation of both active and passive control throughout 2100 to 2400 (i.e., 300 years). During Institutional Control, groundwater monitoring and groundwater quality management will continue to demonstrate compliance with the safety case assumptions. Post-institutional Control occurs after year 2400 and continues indefinitely. Therefore, the main components and activities associated with the post-closure phase of the NSDF Project include:

- ongoing long-term performance monitoring during Institutional Control; and,
- transfer of the NSDF Project into post-Institutional Control.

The following sections present the different phases of the NSDF Project and describes in detail the components and activities anticipated for each phase. Emphasis is placed on the systems, components, and activities of the NSDF Project that are expected to interact with the environment. All activities will be carried out in compliance with CNL's health, safety and environmental protection requirements.

3.1.2 Project Site Overview

As described above, the NSDF Project site is approximately 34 ha, and is almost completely forested. The western portion of the NSDF Project site contains a former abandoned tree research plantation that was planted in the 1950's (Figure 1.0-1). The Petawawa Research Forest has confirmed that this plantation has not been active since the 1980's and is no longer required for research purposes. The legacy Waste Management Area (WMA) A, and four legacy Liquid Dispersal Areas (Reactor Pit 1, Reactor Pit 2, Chemical Pit and Laundry Pit) are located immediately to the northwest, with the CRL Main Campus northeast of the NSDF Project; WMA B, an operating WMA, is located to the west of the NSDF Project site (Figure 1.0-1).

In general terms, the NSDF site is located on both sides of the existing East Mattawa Road which bisects the site crossing north to south. The NSDF northern boundary more or less abuts Power Line Road and the southern boundary to the Dump Road and the Perch Lake Ring Road. On the western side a 30 m setback from the Perch Lake wetlands forms the site boundary and to the east a local ridge line dividing the Perch Lake and Perch Creek watersheds form the boundary. North of the site is forested land and a low lying marsh area is to the west and south, with existing WMA A and B further northwest. The East Mattawa Road leads to Dump Road and the Perch Creek ring road. To the east is forested land which drops down to the CRL Main Campus on the opposite side of the ridge.

The NSDF Project site is located within the Perch Lake basin and groundwater and surface water flow direction reflects the NSDF Project site topography. The general topography of the NSDF Project site is defined by the ridge feature along the eastern extent at approximately 197 metres above sea level (masl). The ridge slopes to the west down to relatively flat terrain at approximate elevation of 156 masl, which ultimately drains to Perch Lake. Groundwater levels range from approximately 0.2 metres below ground surface (mbgs) to 12 mbgs. Surface and groundwater from this basin eventually drain to the Ottawa River, either via Perch Lake and Perch Creek, or directly through Perch Creek. The East Swamp wetland is to the northwest of the NSDF Project site and is connected to Perch Creek via East Swamp stream. No other streams, creeks or other water features are present on the NSDF Project site.

The surficial geology at the NSDF Project site consists primarily of sands, underlain by dense sandy silt till containing cobbles and boulders. Organic soils (e.g., peat) have deposited in the low-lying and wetland areas. The overburden thickness at the NSDF Project site typically ranges from approximately 0 to 22 m, depending on bedrock topography.

3.2 Integrated Waste Strategy

Canadian Nuclear Laboratories IWS for the CRL property includes waste disposal strategies identified for each of the waste classes. The following sections describe the waste types and estimated waste volumes to be disposed of in the ECM, the WAC defined for each waste type, and the process for handling wastes that do not meet the WAC.

3.2.1 Waste Types and Volumes

Sources of the waste to be placed in the ECM will primarily originate from CRL operations and decommissioning activities, including legacy radioactive wastes currently stored on the NSDF Project site, those from future operations, those which will be generated from the demolition and decommissioning of structures at CRL, and the remediation of some contaminated areas at CRL through to 2070. A few percent of the waste volume to be placed in the ECM will be from off-site sources (e.g., CNL's Whiteshell Laboratories, commercial waste sources such as

hospitals and universities). The wastes suitable for disposal in the ECM will include a wide range of bulk and packaged solid radioactive low level wastes and similar waste origins. These wastes have or will arise through CNL activities, including:

- demolition of existing and future buildings;
- remediation of impacted soils and related structures;
- operational and legacy wastes currently in interim storage; commercial sourced inventories; and,
- wastes from the enduring laboratory operations and clean up missions.

Waste characteristic information (i.e., type and volume) is central to determining how waste will be handled, and is the basis for specific waste packaging, handling, and placement practices. Waste information is necessary to select appropriate handling procedures for bulk wastes, routine packaged wastes, and high-activity or high-hazard waste that require special handling or shielding. In addition, for bulk wastes, the waste constituents, such as concrete, wood, brick, and metal must be described to an extent that allows assessment of waste placement efficiency, stability, and optimum placement and waste segregation strategies.

The waste characterization is based on conservative assumptions as most of the waste to be disposed of in the NSDF has not yet been characterized or generated. The properties of future waste are based on projections using known waste that have been fully characterized. A range of waste radiological, chemical and physical properties have been considered and included in the waste characterization. Waste characterization will continue throughout the design, construction, and operation of the NSDF Project. The following section provides a summary of the waste types and expected volumes for each waste type.

3.2.1.1 Waste Types

CRL identifies and tracks several hundred waste sources via its Waste Tracking Database. Each waste is specific to the waste source (e.g., building or process) and includes radiological and chemical characteristics. The method used to identify waste characteristics was to review and compile existing information into a consistent radiological and chemical source term and set of physical characteristics. Wastes are categorized into six waste types as described below.

Type 1 – Soil and Soil-like Waste: Type 1 waste includes contaminated soils and other waste materials with characteristics similar to soil that can be placed within the mound with little to no handling requirements beyond what would be used for soil fill. Environmental remediation activities at CRL site will be the main source of these wastes.

Type 2 – Comingled Debris with Soil or Soil-like Waste: Type 2 waste includes wastes that are anticipated to be at least 50% soil or soil-like in nature, but will also contain varying amounts of refuse containing organic and compressible materials that are considered impractical to separate from the soil or soil-like material. Examples include environmental remediation wastes that are likely to contain materials such as metal, wood debris and trash.

Type 3 – Non-soil-like Waste: Type 3 waste includes waste that can be excavated and handled as a bulk material, but do not have the physical characteristics of soil and soil-like materials. These include primarily materials such as process residues, high organic or highly compressible wastes, high moisture content wastes, flowing wastes (i.e., wastes that do not pass the slump test), and sludges. Examples include contaminated vegetation such as trees.

Type 4 – Decommissioning and Demolition Waste: Type 4 wastes include typical materials used in construction such as concrete, asphalt, brick, lumber, structural steel, process equipment, piping, and other building materials resulting primarily from CRL decommissioning and demolition activities. Type 4 wastes may include some wood, due to the number of wood frame buildings to be demolished. This waste type includes bulk waste materials (e.g., crushed concrete, masonry, asphalt), as well as waste requiring handling and placement as individual pieces (e.g., slab concrete or steel beam sections).

Type 5 – Packaged Waste: Type 5 waste is packaged and includes a variety of containerized wastes such as wastes contained in large shipping containers, B-25 containers, drums, buckets, and pails. These wastes typically require special handling procedures and protocols for placement and containment within the mound. Examples include packaged personal protective equipment and clothing, laboratory glassware and equipment. Packaged waste will not include large steel shipping containers unless the void space inside the container is less than 10% of the container volume. Less than 1% by volume of packaged wastes will be intermediate-level waste (ILW) such as spent ion-exchange resins, compacted trash, immobilized liquids and miscellaneous items. Some of the ILW containerized wastes may require special handling procedures, such as provision of shielding and remote handling to ensure protection of workers from elevated radiation fields.

Type 6 – Miscellaneous Waste: Type 6 waste includes any miscellaneous waste that are encountered or generated at CRL or off-site sources that do not fall within the definition of Waste Types 1 through 5, but otherwise meet the WAC. These wastes will also typically require special handling procedures and protocols for placement and containment within the mound. Examples include oversized equipment, such as tanks that may require use of a crane for emplacement or animal droppings/remains that may require sterilization/sanitation prior to emplacement.

3.2.1.2 Waste Volumes

Table 3.2.1-1 shows the estimated volume of each type of waste expected to be disposed of at the NSDF Project. The most abundant waste types by volume are decommissioning and demolition wastes (Type 4) and soil and soil-like wastes (Type 1). Over 80% of the wastes will be bulk unpackaged wastes. Approximately 15% of the wastes will be packaged. Of the wastes, approximately 1% by volume will be ILW (Section 3.2.2.2). These wastes will be demonstrated to meet environmental and safety objectives.

Table 3.2.1-1: Phase 1 and 2 Waste Types and Volumes

Waste Type	Waste Volume (m^3)	Waste Type (%)
Type 1 – Soil and Soil-like Waste	370,000	37
Type 2 – Comingled Debris with Soil or Soil-like Waste	80,000	8
Type 3 – Non-soil-like Waste	10,000	<1
Type 4 – Decommissioning and Demolition Waste	390,000	39
Type 5 – Packaged Waste(a)	150,000	15
Type 6 – Miscellaneous Waste	10,000	<1
Total(b)	**1,000,000**	**100**

<= less than; m^3 = cubic metres; % = percent.

(a) Approximately 1% of the waste by volume will be ILW. These wastes will be demonstrated to meet environmental and safety objectives.

(b) Due to rounding numbers may not appear to add up to total.

3.2.2 Waste Acceptance Criteria

The WAC, along with adequate waste characterization, are essential for ensuring only waste with acceptable physical, radiological, and chemical characteristics is emplaced in the ECM. Specifically, the WAC are developed for the following purposes:

- provide quantitative limits (applicable to the disposal of radioactive waste in the ECM) that are protective of workers, the public and the environment;
- ensure waste conforms to operational and ECM post-closure safety case requirements;
- provide safe handling of waste under normal and operational conditions including anticipated upsets; and,
- identify relevant parameters that will influence the facility design and safety case for radioactive waste to be emplaced in the ECM so that each criterion is considered and accounted for.

The development of the WAC is an iterative process that occurs in parallel with the development of the safety analysis, performance assessment, facility design, and the environmental assessment process. The development of the WAC is based on the interpretation and application of IAEA guidelines, relevant regulations and WAC documents from other approved similar waste disposal sites. In addition, the WAC are based on Canadian Standards Association (CSA) standards, and CNL's strategic planning and stakeholder workshops.

Radiological limits for WAC were determined in a manner designed to ensure that NSDF can meet safety objectives while maximizing potential range of suitable waste. A three-step approach was used to define activity limits and screen potential waste.

1) Define evaluation criteria;
2) Evaluate each waste stream against criterion defined; and
3) Define activity limits and suitable waste.

Six separate criteria were considered in selecting WAC, as defined by a group of subject matter experts. Ultimately, only the following two criteria were determined to be essential in defining radiological limits for NSDF WAC:

1) Meeting Performance Assessment Safety objectives, and
2) Proven technology.

Requirements relating to ensuring Criticality Safety and potential constraints on the quantities of fissile material and hazardous chemicals were considered using separate analyses. Other, operational safety objectives, such as WWTP operations and compliance with the ALARA principle were considered. It was concluded that these requirements can be met through appropriate design measures and operational systems and should not impact radiological limits for WAC.

Based on the analysis of long-term performance of NSDF (criterion 1) and benchmarking against WAC for existing near-surface disposal facilities (criterion 2), it is recommended that the total specific activity of any waste consignment accepted for disposal at NSDF shall not exceed the following values:

- 4,000 Becquerels per gram (Bq/g) for all alpha-emitting radionuclides; and,

- 100,000 Bq/g for all long-lived beta radionuclides.

Wastes having activity greater than 400 Bq/g for alpha-emitting radionuclides and 10,000 Bq/g for long lived beta radionuclides will require special packaging and/or treatment to ensure the radioactive wastes remain isolated and contained in the waste packages. Hazardous waste is not acceptable for disposal in the NSDF and will not be emplaced in the NSDF, unless as a co-contaminant in mixed waste (see Section 3.2.2.1.3) and generally meeting Land Disposal Requirements as provided in Ontario *Environmental Protection Act*, Regulation 347.

3.2.2.1 Physical Characteristics

The NSDF Project will only accept solid waste with no free liquids for disposal. Waste that has been rendered solid via stabilization (e.g., cementation) or pre-treatment may meet this requirement. Waste will either be delivered to the ECM in the form of bulk materials or packaged wastes. The majority of the waste to be accepted in the ECM will be bulk materials (i.e., Types 1, 2, 3 and 4 from Table 3.2.1-1); these will include the following:

- pipes;
- miscellaneous metals, building debris waste, concrete debris and rebar, structural steel, or conduit;
- general building rubble; and,
- soil, sand and stone.

Packaged waste (Type 5) comprises approximately 15% of the total waste volume to be accepted in the ECM. The primary objective of waste packaging is based on two principles: 1) containment of radioactive materials to prevent radionuclide release into the environment; and 2) providing shielding against ionizing radiation. The properties of the container must also be compatible with the enclosed waste. The types of waste packages to be emplaced in the ECM include the following:

- drums, which may be galvanized, stainless, carbon steel, or plastic construction;
- boxes, which may be galvanized, stainless steel, or wood;
- soft-sided packages, which may include hessian sacks; and,
- large containers, roll-off bins and intermodal containers such as International Organization for Standardization (ISO) containers.

Containers and packaging will meet the WAC requirements for dimension and mass in order to assure safe handling and on-site transportation of the package. A very small percentage of containerized waste may require concrete shielding containers (e.g., concrete caissons) for worker protection during handling. Packages will have a label or another unique identifier to enable waste tracking and to associate waste characterization records.

3.2.2.2 Radiological Characteristics

Waste has been defined as suitable for disposal in the ECM on the following basis:

- limited concentrations of long-lived alpha-emitters, fission and activation products, such that long-term safety objectives can be met;
- limited concentrations of fissile materials, such that criticality safety can be assured during the NSDF Project operations and post-closure; and,

- proven track record of successful disposal of similar waste types in near surface repositories in other jurisdictions.

A few percent of containerized ILW (i.e., Type 5 waste) has been included in the NSDF Project waste inventory. The total volume of such waste type is estimated to represent about 1% of the total emplaced volume (i.e., 1% of 1,000,000 m^3). Such types may include containers with ion exchange resins, compacted trash and small quantities of other miscellaneous items. All ILW will be required to meet safety objectives and be bounded by the safety case.

The majority of radiologically contaminated wastes will meet requirements for LLW handling. A small quantity of the containerized ILW may need to be remotely handled for worker protection. Radiological dose rates and surface contamination on containers will meet CNL's Radiation Protection Program requirements and be required to meet safety objectives and be bounded by the safety case.

The dose rate limits of Type 5 waste packages for contact-handleable waste are as follows:

- the maximum gamma-radiation level of each waste package, measured on contact, must be less than 2 millisieverts per hour (mSv/h);
- the maximum gamma-radiation level of each waste package, measured at 1 m, must be less than 0.1 mSv/h; and,
- the maximum beta-particle radiation field of each waste package, measured on contact, must be less than 10 Sv/h.

The dose rate limits of waste packages are as follows for remote handling:

- the maximum gamma-radiation level of each waste package, measured on contact, must be less than 50 mSv/h;
- the maximum gamma-radiation level of each waste package, measured at 1 m, must be less than 1 mSv/h; and,
- the maximum beta-particle radiation field of each waste package, measured on contact, must be less than 200 mSv/h.

The maximum non-fixed surface contamination on the outer surface of each waste package, averaged over 300 square centimetres (cm^2), must be less than 3.7 Becquerels per square centimetre (Bq/cm^2) for beta/gamma-emitters, and less than 0.37 Bq/cm^2 for alpha-emitters.

Fissile material limits for packages and the facility will be developed using CNSC's Guidance for Nuclear Criticality Safety, GD-327 and meet the requirements of CNL's Nuclear Criticality Safety Program, such that criticality safety can be assured (see Section 3.13.2.6).

Waste accepted in the ECM will have minimal heat generation; waste shall have a thermal power rate below 2 kilowatts per cubic metre (kW/m^3) for LLW in accordance with CSA Standard N292.0-14 *General Principles for the Management of Radioactive Waste and Irradiated Fuel*.

3.2.2.3 Chemical Characteristics

The majority of radioactive wastes accepted in the ECM will be on-site building waste from decommissioning and soil and soil-like wastes from environmental restoration. A few percent of these radioactive wastes may contain hazardous substances such as asbestos, heavy metals or organics and are referred to as 'mixed wastes'. Mixed wastes may be accepted for disposal in the ECM provided that they meet the intent of land disposal and leachate requirements specified in the Ontario *Environmental Protection Act*, *Regulation 347 General Waste Management*. Examples of hazardous substances that may be included in the mixed wastes for disposal in the ECM are:

- asbestos, in the form of pipe lagging, tiles, transite;
- petroleum contamination in waste that results from spill cleanup, bitumen, sealants, and protective equipment contaminated with traces of solvents (e.g., organic vapour carbon respirator cartridges, gloves and suits);
- toxic materials (e.g., lead shielding or piping, lead in paints, foam insulations, fibreglass and epoxy coatings, and insecticides/pesticides/herbicides);
- chemical complexing or chelating agents;
- electrical equipment containing batteries (e.g., monitoring equipment, smoke detectors, back-up lighting); and,
- materials contaminated with trace quantities of Polychlorinated Biphenyls (PCB[1]).

Hazardous materials shall be segregated from mixed wastes to the extent practical. In cases where segregation is not possible (e.g., painted surfaces) or As Low As Reasonably Achievable (ALARA), mixed wastes will be safely disposed in the ECM. In cases of mixed wastes that include dusts, asbestos, and other dispersible or toxic characteristics these wastes will be packaged or containerized by the waste generator prior to shipment to the NSDF for disposal.

[1] Mixed waste having total PCB concentration of up to 50 ppm may be accepted by the NSDF.

The list of acceptable disposal wastes in the ECM will be further refined through the development of the WAC and facility design for the NSDF Project. The following wastes will not be accepted for disposal in the ECM:

- ozone depleting substances and other halocarbons;
- pyrophoric materials, explosive and / or dangerously reactive materials;
- compressed gases; and,
- biomedical, infectious and pathogenic materials (biological materials such as vegetation and animal carcasses may be allowed).

3.2.3 Waste Acceptance Criteria Variance Process

Wastes that meets the WAC will be accepted. In the rare occasion that wastes that do not meet the WAC, the waste may be further reviewed for acceptance through the WAC variance process. In order to obtain a variance for a specific waste, the following steps will take place.

3) The waste will be analyzed to identify the radiological, chemical, or physical criteria that the waste cannot meet.

4) The generator will prepare an exemption request and submit it to the Waste Management organization.

5) If a safety argument can be made, the Waste Management organization will determine and approve a procedure for reviewing and accepting this waste. This may include special handling requirements or precautions or additional processing to make the waste acceptable.

6) If a safety argument cannot be made, the NSDF will not accept the waste for disposal. The generator will have to make other arrangements such as waste processing and treatment, off-site disposal, or disposal at another type of facility.

3.3 Project Requirements

The NSDF Project is being developed in keeping with numerous design (which includes regulatory requirements) and strategic requirements as relevant to the development of the NSDF Project. These requirements are discussed in the following sections.

3.3.1 Design Requirements

According to the IAEA *Technical Considerations in the Design of Near Surface Disposal Facilities for Radioactive Waste* (2001), the following are fundamental design principles relating to the safe management of radioactive waste and disposal.

- Protection of human health – radioactive waste shall be managed in such a way as to secure and acceptable level of protection for human health.
- Protection of the environment – radioactive waste shall be managed in such a way as to provide an acceptable level of protection of the environment.
- Protection of future generations – radioactive waste shall be managed in such a way that predicted effects on the health of future generations will not be greater than relevant levels of effects that are acceptable today.

- Burdens on future generations – radioactive waste shall be managed in such a way that will not impose undue burdens on future generations.
- Safety of facilities – the safety of facilities for radioactive waste management shall be appropriately assured during their lifetime.

Consistent with the above principles, the objective of the design of a near surface disposal facility is to ensure the facility can be built and waste received, handled, and disposed of without undue risk to human health and the environment, both during the facility operation and after facility closure (IAEA 2001). The NSDF Project, in accordance with IAEA Specific Safety Requirement 9 (IAEA 2011), will be sited, designed and operated to provide features that are aimed at the isolation of the radioactive waste from people and the environment.

The NSDF Project will provide containment of radioactive contamination for a minimum of 500 years until it has decayed to levels that do not present a risk to the public and environment[2]. The design of the NSDF Project must also meet CNL's Compliance Programs (Section 3.13):

- Radiation Protection Program;
- Environmental Protection Program;
- Waste Management Program;
- Occupational Safety and Health Program;
- Emergency Preparedness Program;
- Nuclear Criticality Safety Program;
- Physical Security Program;
- Nuclear Materials and Safeguards Management Compliance Program; and,
- Fire Protection Program.

3.3.2 Strategic Requirements

The disposal facility must meet the following strategic requirements:

- be available by 2020 to enable the CRL site revitalization through improved environmental management of Government of Canada legacy waste liabilities and the decommissioning of outdated infrastructure at the CRL property and other business locations; and,
- provide for the long-term safety, and provide an acceptable level of protection, to the public and the environment.

[2] A substantial amount of the waste would exceed unconditional clearance levels after 500 years. The Safety Analysis Report demonstrates that even after failure of some of the design features, the wastes do not present a risk to the public and environment (see Section 5.0).

3.4 Preparation of the Site

Site preparation involves the works and activities, which are essentially large-scale earth moving activities using conventional earth moving equipment, required for the preparation of the NSDF Project site for construction. This includes mobilization of the necessary construction equipment and those activities related to the removal of trees, excavation and hauling of soil, and grading. Radiological surveying and soil analysis will be carried out prior to site preparation in accordance with existing soil management procedures.

Assuming an environmental assessment decision in January 2018, NSDF Project site mobilization of construction equipment would occur by April 2018 and the remaining site preparation activities (i.e., soil excavation and hauling, grading) would be complete between April and July 2018. Equipment required for site preparation are shown in Table 3.4.1-1.

Table 3.4.1-1: Equipment Required for the NSDF Project Site Preparation Activities

Equipment	Estimated Quantity (units per day)
Rock Truck	2
Dump Truck	14
Water Truck	2
Excavator	4
Bulldozer	1
Grader	1
Roller (Soil Compaction)	1
Roller (Pavement Compaction)	1

Specific activities associated with the NSDF Project site preparation include the following:

- clearing and grubbing of vegetation (e.g., brush and trees);
- excavating, removing, and stockpiling of topsoil for later use for the ECM final cover system;
- blasting and excavation for the ECM;
- removal and/or stockpiling of waste rock;
- excavating all ditches and the surface water management ponds;
- grading the NSDF Project site including grading of access roads, WWTP, laydown and stockpile areas, and various other building locations; and,
- establishing exclusion and buffer zones.

Rock blasting will be required to complete site preparation activities for the NSDF Project site. Blasting activities will be done by a qualified person and in accordance with the Blasting Plan to be developed indicating the type of explosives used and the method of detonation. Additional guidance for the NSDF Project blasting limits will be obtained from the Ontario Provincial Standard Specification (OPSS) in the document OPSS 120 – General Specification for Use of Explosives (OPSS 2008). Blasting activities will follow industry standard Best Management

Practices, applicable federal regulations, and Department of Fisheries and Oceans Canada (DFO) guidelines for use of explosives.

The NSDF Project site preparation will begin following receipt of approval of the environmental assessment and will take approximately four months to complete. The preferred timing for completion of clearing and grubbing of vegetation on the NSDF Project site is between February and April 2018 to mitigate potential effects to migratory birds and other wildlife species (i.e., outside of sensitive timing period).

A 30 m buffer is established along all identified wetlands near the NSDF site. In addition to the wetlands buffer, a 5 m tree-line buffer is established from all property lines on the NSDF site in order to limit disturbance to vegetation and large tree roots at the tree-line. Buildings or structures will not be situated within 5 m of this buffer zone (i.e., 10 m from property line) to provide access for equipment around structures. A buffer zone will also be maintained between the waste and the boundary of the disposal site. This zone provides sufficient area surrounding the facility operations to allow environmental monitoring to be performed, facilitate maintenance, and to allow implementation of contingency measure during an emergency.

The total land area to be cleared is up to 34 ha, most of which is treed. Where required, trees will be felled, skidded and piled in an area for removal from the NSDF Project site. To allow trees to be removed from the NSDF Project site, sampling will be completed as per CNL's Management of Land and Habitat procedure to verify that the material meets radiation specifications for off-site use. Roots, stumps, embedded logs and debris will be removed by grubbing and will be disposed of according to existing management practices. Stripping of the soil is required to remove topsoil and organic material, where necessary. The topsoil will be stored in piles for later use for the ECM final cover system. Excavation for the ECM, drainage ditches, and the surface water management ponds will be completed once the NSDF Project site has been cleared and topsoil removed. Details associated with the construction of the ECM are provided in Section 3.5.2. Grading will be completed for the WWTP, other building locations, and access roads.

3.5 Construction Phase

The key surface structures are the ECM, WWTP, access roads and support facilities. Surface construction methods will be consistent with those used for existing waste management areas, infrastructure, and support facilities on the CRL property. Construction activities are expected to take approximately two years to complete, starting in April 2018 and completion in 2020.

The contractor will conduct administrative controls, such as pre-job briefs and the use of Work Permits, as per CNL's Occupational Safety and Health Program to control or eliminate hazards in the field that may be encountered during NSDF Project site preparation and construction activities. An Environmental Protection Plan will also be implemented to reduce or eliminate environmental effects associated with these activities. The Environmental Protection Plan will be similar to that in place for other CRL projects and includes measures such as water spraying to control dust, vehicle maintenance standards to reduce emissions, and implementation of erosion and sediment controls (see Section 3.14.2.5 for more details on this plan).

Fuels, lubricants and chemicals required for mechanical construction equipment will be delivered to the NSDF Project site in appropriately-qualified vehicles and/or containers and dispensed and used, all in compliance with applicable legislation, codes and practices. Proper handling, storage and disposal of these materials will be achieved through compliance with Environmental, Waste Management and Occupational Safety and Health

Programs. Restrictions on the use of designated locations for fueling, lubrication and servicing of equipment, inspection requirements, storage requirements and spill clean-up procedures will be included in these procedures.

The following sections describe site preparation, construction activities, and the design of the ECM, WWTP, operational support facilities and site infrastructure required for the NSDF Project. The proposed layout of these facilities is shown on Figure 3.1.1-1.

3.5.1 Construction Materials

It is estimated that approximately 200,000 m^3 of various soil and granular materials plus an estimated 400,000 square metres (m^2) of geosynthetic products (e.g., geomembrane, geosynthetic clay liner, and geotextile) will be transported to the NSDF Project site for construction of the ECM base liner (Table 3.5.1-1). These material estimates are preliminary, based on initial engineering and are subject to change as the design progresses. Estimated material requirements for the final cover are provided in Table 3.5.1-2. Final cover construction will result in similar delivery requirements as needed during the construction period.

It is estimated that 155,000 m^3 of soil will be excavated for the initial design fill capacity of 525,000 m^3 of waste, with roughly an additional 125,000 m^3 of soil excavated for the expansion to 1,000,000 m^3 of waste. The volume of excavated soil will be sufficient to meet the soil volume requirements for the daily/interim cover and for placement of the final cover. Any surplus soil from the excavation will be used to cover the disposal cells and as landscaping fill during closure. Suitable clay soil for the construction of the clay component of the base liner system will be imported from an off-site source.

Table 3.5.1-1: Estimated Material Requirements for the Engineered Containment Mound Base Liner

Engineered Containment Mound	Clay (m^3)	Drainage Media (m^3)	Geomembrane (m^2)	Geotextile (m^2)
Phase 1	53,000	44,000	71,000	71,000
Phase 2	53,000	44,000	71,000	71,000
Total	106,000	88,000	142,000	142,000

m^2 = square metres; m^3 = cubic metres.

Material estimates are preliminary, based on initial engineering and are subject to change as the design progresses.

Table 3.5.1-2: Estimated Material Requirements for the Engineered Containment Mound Final Cover – Phase 1

	Topsoil (m^3)	General Fill Soil (m^3)	Geotextile (m^2)	Coarse Stone (m^3)	Sand (m^3)	Geomembrane (m^3)	Geosynthetic Clay Liner (m^3)
Total	16,400	110,000	110,000	22,000	22,000	110,000	110,000

m^2 = square metres; m^3 = cubic metres.

Material estimates are preliminary, based on initial engineering and are subject to change as the design progresses.

While other aspects of the ECM construction will involve additional materials, their quantities are generally not substantial relative to those associated with the base liner and final cover. An exception will be the requirement for the granular and earth fill materials for the perimeter berm and access road construction, which will total approximately 400,000 m^3 (approximately half this volume for Phase 1, and half for the second phase).

The haulage route for transportation of NSDF Project site preparation and construction equipment, and construction materials will be via public roads to the CRL property (e.g., Highway 17) and will be scheduled to reduce noise and traffic volumes, and limit inconvenience to local residents. Construction materials (e.g., processed granular materials and gravel, geosynthetic products and clay) will be transported to the NSDF Project site using standard highway haul vehicles. Within the CRL property, transport of site preparation and construction equipment, and construction materials to the NSDF Project site will be by the Plant Road, which leads to the main site access road.

3.5.2 Engineered Containment Mound

The primary component of the NSDF Project is the ECM, which will contain the wastes and isolate them from the surrounding environment.

3.5.2.1 Containment Mound Fill Capacity

The fill capacity of the ECM is designed to accommodate 525,000 m^3 of waste, with the possibility of expanding up to 1,000,000 m^3 of waste. The daily/interim cover soil design uses an industry-typical waste-to-soil ratio of 4:1 (i.e., 4 units of waste for every 1 unit of daily/interim cover soil), which results in a total cover soil volume of 131,250 m^3. As such, the design fill capacity for the mound volume is 656,250 m^3 (i.e., 525,000 m^3 of waste, plus 131,250 m^3 of daily/interim cover soil), and the design fill capacity for the expansion would be 1,250,000 m^3 of waste and daily/interim cover soil (i.e., 1,000,000 m^3 of waste, plus 250,000 m^3 of daily/interim cover soil). The design capacity for the mound volume as described above does not include the final cover volume, base liner volume, or perimeter berm volume.

3.5.2.2 Disposal Cells

The ECM design consists of a total of ten individual, but contiguous disposal cells are expected to be filled over the 50-year operating life. The cells are designed to maintain structural integrity and to retain their confinement for 500 years. The cells run parallel in rows and the cells are designed for a maximum of 18 m of fill, waste, and cover above, and are designed for varying combinations of permanent, variable, thermal, seismic, and hydraulic loads. The cells vary in size, but generally have a surface area of approximately 12,000 m^2. The cell design accounts for shielding requirements, WAC, and are located to provide operational flexibility, in consideration of waste type and frequency.

The cell development sequence provides for progressive construction, infilling and closure of the individual cells. The disposal cells will be filled in successions. As each cell is filled to capacity, the next cell will be ready to accept waste. Each cell will operate for about 5 years. When a cell is nearly full, the subsequent cell will be prepared to receive waste, so disposal operations can proceed without delay. The filled cells will first be covered with interim soil layer 0.5 m thick to limit contact with stormwater. The final cover, containing an HDPE membrane, will be constructed in phases. The final cover is assumed to be constructed over Cells 1 through 3 when they are filled. The next stage of final cover construction will include Cells 4 through 6, and the final stage will cover Cells 7 through 10.

3.5.2.3 Base Contours

The design of the base contours is affected by a number of factors, including the total mound capacity, site development sequences, leachate collection system layout, and seasonal high groundwater level. The base contours for the ECM have been developed using a herringbone design with ridges and valleys to promote

leachate transport to the leachate collection system for removal. The herringbone base contours, in conjunction with the spacing of the leachate collection pipes, provides that the drainage path for leachate to reach a collection pipe is not more than 50 m long.

The base grade at the south end of the NSDF Project site is a 10% slope, which transitions to a 5% slope over the remainder of the base. This configuration was used because of the bedrock plateau near the centre of the mound base, and to maximize available volume for waste materials. The cross-fall on the herringbone ridges is 3% to the to the leachate collection system and leak detection system lateral collection pipes.

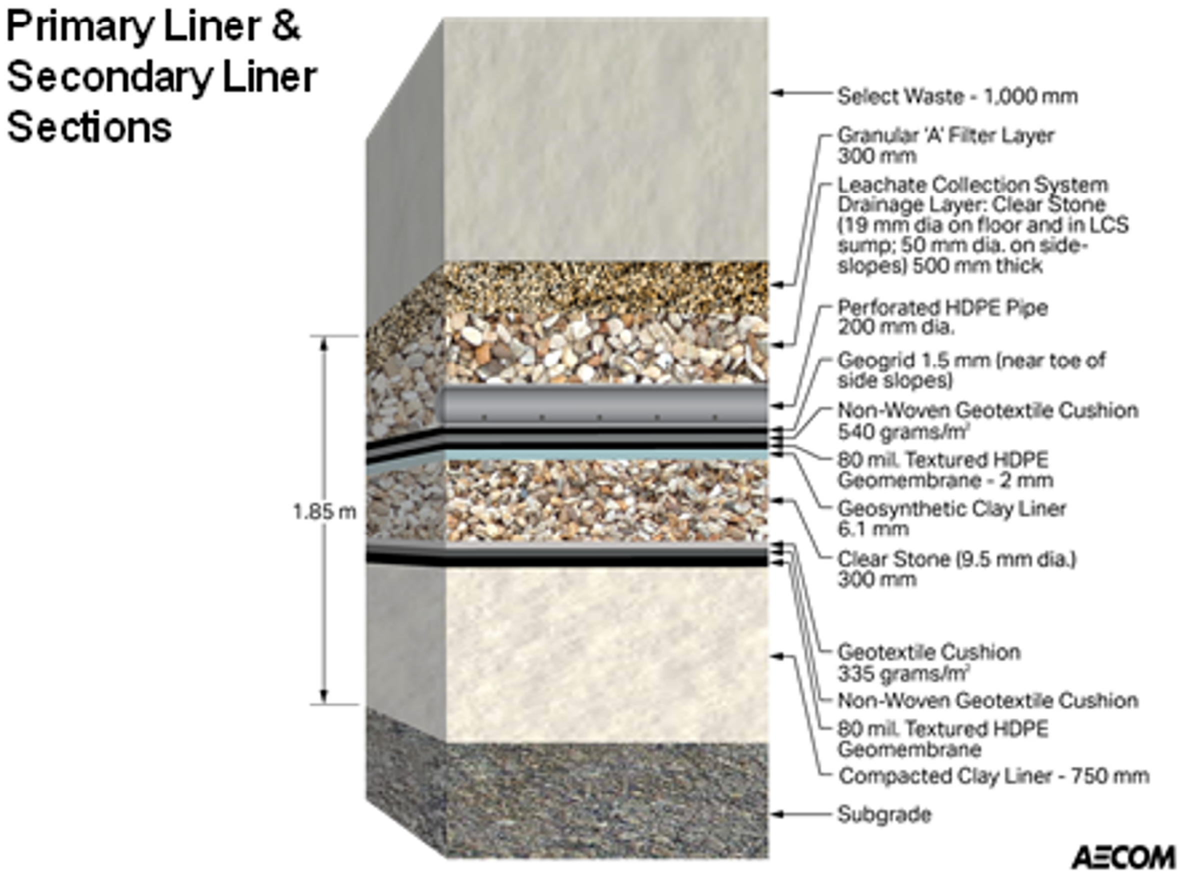
3.5.2.4 Base Liner

The base liner design include both primary and secondary liner systems that are designed to have redundancy in case of premature failure and are a combination of natural and synthetic barrier systems. A compacted clay liner 0.75 m thick is placed on top, followed by a series of high-density polyethylene (HDPE), geosynthetic, and earthen layers to give a total thickness of the base liner system of 1.85 m. The composite base liner is designed to be at least 1.5 m above groundwater at all times. The hydraulic conductivity of the clay portions of the primary and secondary liner system is 1.0×10^{-7} or less. A cross-section of the composite base liner is shown on Figure 3.5.2-1.

The primary liner will include a leachate collection system with the secondary liner housing a leak detection system. The composite base liner will contain perforated HDPE collection and monitoring pipes. The base liner system will include an underlying compacted clay liner to supplement the primary and secondary liner system. The leachate collection and monitoring system design will provide accessible access points for monitoring, inspections, maintenance, repairs and replacements.

The HDPE geomembrane was selected as it is compatible with the leachate generated by the waste and will achieve a long service life. The primary form of degradation of the geomembrane liner component of the final cover and base liner is considered to be oxidative degradation, which leads to a reduction in stress crack resistance and a reduction in tensile strength/strain at break. Based on reported laboratory studies involving exposure of the geomembrane to accelerated oxidation conditions, the service life of the geomembrane liner with respect to oxidative degradation is expected to be greater than 700 years and probably on the order of 1,000 years (or longer). Based on the review of results from several studies conducted to evaluate the service life of HDPE geomembranes, an HDPE geomembrane installed in the final cover and basal lining systems of the ECM is expected to perform as an effective hydraulic and diffusion barrier over the 500-year design life of the ECM.

The primary liner system will contain the leachate collection system, and will convey leachate to a single collection point for removal from the mound. The primary liner system will also protect the natural environment below the mound from leachate migration, and will maintain a maximum depth of leachate on the geomembrane liner of less than or equal to 300 mm. The secondary liner system will contain the leak detection system, which will be used to detect leaks in the unlikely event that the primary liner system fails. The secondary liner will also protect the natural environment from leachate migration if the primary liner system fails. The following provides details for both the primary and secondary liner and corresponds to information provided on Figure 3.5.2-1.



REFERENCE(S)
1. FIGURE OBTAINED FROM CNL (MARCH 2017)

CLIENT
CANADIAN NUCLEAR LABORATORIES

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT

TITLE
CROSS-SECTION OF THE BASE LINER

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	MM
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0004	0.0	**3.5.2-1**

The primary liner comprises the following different layers as part of its design.

- A non-woven geotextile will limit the migration of fines from the overlying waste material into the granular drainage layer.
- A granular drainage layer (300 millimetres [mm]-thick course aggregate) with primary function of leachate collection, monitoring and removal. This layer will form the basis of the leachate collection system. The drainage layer material will be of sufficient quality to obtain a minimum hydraulic conductivity of 1.0×10^{-2} centimetres per second (cm/s). This minimum hydraulic conductivity is based on standard industry practice for a layer for this purpose.
- A double-sided geocomposite drainage layer will protect the HDPE geomembrane liner when the granular drainage layer is placed. This layer will also provide additional pore space to assist with dewatering and leachate transmissivity during waste placement.
- A 2-mm HDPE geomembrane liner will serve as a hydraulic barrier to the leachate from both the granular drainage and geocomposite layers.
- A geosynthetic clay liner (GCL) will provide a secondary protection layer below the HDPE geomembrane. The sodium bentonite from the GCL core hydrates and seals with water contact, which will mitigate defects and damage in the HDPE geomembrane that could result from the manufacturing process or placement.

The secondary liner comprises the following different layers as part of its design.

- A secondary drainage layer (300-mm-thick coarse aggregate) will collect or drain, or both, leachate that may have migrated through the primary liner system. This layer will also consist of a series of monitoring points and piping to monitor leak detection in the primary liner system. The drainage layer material will be of sufficient quality to obtain a minimum hydraulic conductivity of 1.0×10^{-2} cm/s. This minimum hydraulic conductivity is based on standard industry practice for a layer for this purpose.
- A non-woven geotextile layer will protect the geomembrane against damage or penetration from the secondary drainage layer.
- A 2-mm HDPE geomembrane liner will serve as a hydraulic barrier to the leachate and groundwater.
- A Compacted Clay Liner (CCL; 750 mm thick) will provide a natural seepage-free barrier against the migration of leachate or liquid, or both, through the secondary liner. The compacted clay liner will be of sufficient quality to obtain a maximum hydraulic conductivity of 1.0×10^{-7} cm/s. This maximum hydraulic conductivity is based on standard industry practice for a layer for this purpose.

3.5.2.5 Berms

Berms form the outer boundaries and sidewalls for most of the perimeter of the ECM and make the ECM a containment system. They are formed of soil or rock and compacted. All berm side slopes are 3 horizontal (H) to 1 vertical (V), with a 7 m width at the top. Heights of the berms vary from 1 m to 15 m. Designed berms consist of three main geotechnical elements, or layers, each contributing to the soundness and integrity of the berm itself and the whole ECM. The inside face of the berm will be covered with the various liner system layers, while the outer face will be covered with the intrusion barrier rockfill over geomembrane, geotextile cushion and geogrid.

The top of the berm is covered with various layers of granular A material, geomembrane and geotextile cushion with the top layer granular A becoming the top of berm roadway.

A Slope Stability Analysis was completed to provide the information needed to support the design of the base slopes, sidewalls, and side slopes of the ECM. The Slope Stability Analysis addresses the range of anticipated loading conditions, under both short-term and long-term scenarios, to confirm that the slope designs will satisfy minimum factor-of-safety requirements for stability. Size and shape of the berms and each of the elements and layers were determined using a seismic design basis.

3.5.3 Wastewater Treatment Plant

This section describes the facilities to be constructed and processes implemented to treat wastewater associated with the construction and operation of the ECM. The strategy for wastewater treatment is based on optimizing public and environmental protection by defining an approach to wastewater treatment that uses best demonstrated available technology that is economically achievable (BDATEA), and capable of meeting regulatory requirements. The WWTP for the NSDF Project will be a new, stand-alone facility with a new discharge. No changes are anticipated for the existing wastewater treatment system at CRL as part of the NSDF Project.

3.5.3.1 Wastewater Flows and Characteristics

The new WWTP will be designed and constructed to meet the ongoing treatment requirements for the effluent from the following sources:

- leachate generated from precipitation that infiltrates into the placed waste in the ECM;
- potentially contaminated surface water collected from the active waste disposal area (i.e., precipitation collected from the surface of the open waste cells during operations that has not infiltrated into the waste);
- potentially contaminated surface water flows from any site roads used to haul waste material to the ECM;
- potentially contaminated surface water that have intercepted the ECM and into the leachate collection system;
- construction and operating equipment decontamination and wash water; and,
- washroom and personnel decontamination facilities and other on-site service areas where the potential for contaminated flows exists, such as the WWTP process laboratory (this does not include sewage, which will be sent to a separate system).

Three categories of wastewater have been defined and the quantity of each has been estimated separately. The three categories are: 1) leachate; 2) surface contact water; and 3) decontamination water. Leachate and contact water quantities are estimated based on a water balance calculation completed with the Hydrologic evaluation of Landfill Performance (HELP) model. The maximum average annual wastewater volume to be produced during operations is when ECM Cells 1 through 6 are filled and closed with final cover, Cells 7 through 9 are filled and closed with an interim cover, and Cell 10 is active. The total average annual volume of leachate, contact stormwater, and decontamination water under this operating scenario is 6,556 cubic metres per year (m^3/year).

Another important hydraulic design consideration is the maximum wastewater flow rate that must be received and processed by the WWTP. Leachate and decontamination water are produced at relatively low rates compared to contact stormwater, especially during major storm events. The projected average leachate flow from a single

closed cell with final cover is 0.001 cubic metres per hour (m^3/hour). The projected average leachate flow from a single closed cell with interim cover is 0.07 m^3/hr. The maximum hydraulic flow rate was determined by evaluating the expected contact stormwater volume that would be produced during back-to-back 100-year, 24-hour storm events. Under these conditions, it is expected that 2,820 m^3 of contact stormwater would be produced, and that this contact stormwater would be removed from the ECM at a maximum rate of 59 m^3/hour. This was selected as a worst-case design condition for determining the required volume of wastewater equalization.

The chemical and radionuclide concentrations in leachate are calculated using a partitioning model that assumes that the ratio of the contaminant concentration in the solid phase to the contaminant concentration in the leachate is constant. The partitioning factor frequently used is known as the distribution coefficient (K_d). Contaminants with low K_d values preferentially partition into the liquid phase, whereas contaminant with high K_d values remain primarily absorbed onto solid particles. Partitioning models are commonly used in radiological assessments to determine leaching characteristics of radionuclides and metals in soil and soil-like wastes. The partitioning factors were taken from the CSA Standard N288.1-14. These factors conservatively estimate the leachate characteristics.

The radionuclide concentrations in wastewater are a combination of the leachate concentrations and the leachate volume, combined with the contact water and decontamination volumes (Table 3.5.3-1). The contact water is assumed to have very low radionuclide concentrations because of the effects of daily ECM cover and water management practices within the disposal cell. Decontamination water is assumed to have the same radiological and chemical characteristics as the wastewater from the ECM. In the absence of quantitative information, non-radioactive waste constituents were developed from information gathered from other sites and the expected characteristics of wastes to be disposed of in the NSDF. These values present a reasonable and conservative estimate of concentrations in wastewater such that the WWTP design is capable of treating wastewater to meet applicable surface release limits.

The effluent concentrations were compared to treatment targets based on the CRL Acceptability Criteria for Routine and Non-Routine Discharge of Liquids to Stormwaters for all parameters except tritium. The treatment targets were used as screening levels to identify those parameters that may require treatment at the WWTP and/or development of a site-specific limit. Table 3.5.3-1 and Table 3.5.3-2 summarizes the treated wastewater effluent requirements, for radionuclides and non-radioactive constituents, respectively. A total of 12 radionuclides and 11 non-radionuclide constituents require treatment in order to meet the required treatment targets.

Table 3.5.3-1: Radionuclide Concentrations in Wastewater and Treatment Targets

Constituent	K_d (ml/g)[(a)]	Concentration in Waste (Bq/g)	Concentration in Wastewater (Bq/L)	Treatment Target[(b)] (Bq/L)	Treatment Required?
Actinium-227	576	6.47×10^{-8}	7.6×10^{-9}	0.1	No
Americium-241	**4,300**	**1,460**	**24**	**0.7**	**Yes**
Americium-243	4,300	0.00365	0.00011	0.7	No
Carbon-14	**20**	**306**	**1,000**	**200**	**Yes**
Cesium-134	370	0.103	0.130	7	No
Cesium-135	370	0.0496	0.0090	70	No
Cesium-137	**370**	**31,800**	**0.0050**	**10**	**Yes**
Chloride-36	**6**	**37**	**400**	**100**	**Yes**
Cobalt-60	**640**	**58,500**	**2,700**	**40**	**Yes**

Constituent	K_d (ml/g)[(a)]	Concentration in Waste (Bq/g)	Concentration in Wastewater (Bq/L)	Treatment Target[(b)] (Bq/L)	Treatment Required?
Curium-244	**18,000**	**55.2**	**1.7**	**1**	**Yes**
Europium-154	429	0.314	0.37	70	No
Hydrogen-3	0	30,600	9,100,000	—[(c)]	(c)
Iodine-129	**18**	**418**	**1,500**	**1**	**Yes**
Lead-210	450	1.62×10^{-9}	2.4×10^{-10}	0.2	No
Molybdenum-93	125	5.58×10^{-6}	3.0×10^{-6}	40	No
Neptunium-237	25	0.00125	0.022	1	No
Nickel-59	140	37.3	18	2,000	No
Nickel-63	140	525	240	900	No
Niobium-94	2,500	5.16	0.90	80	No
Plutonium-238	**1,100**	**5.80**	**3.3**	**0.6**	**Yes**
Plutonium-239	**1,100**	**15.5**	**8.2**	**0.6**	**Yes**
Plutonium-240	**1,100**	**9.63**	**5.4**	**0.6**	**Yes**
Plutonium-241	1,100	0.0680	0.0028	30	No
Plutonium-242	1,100	7.05×10^{-4}	4.3×10^{-5}	0.6	No
Protactinium-231	1,800	2.70×10^{-7}	1.0×10^{-8}	0.2	No
Radium-226	1,900	4.05	0.14	0.5	No
Ruthenium-106	40	0.000839	0.0084	20	No
Selenium-79	220	0.00236	0.00072	6,050	No
Silver-108m	120	0.0103	0.0055	60	No
Strontium-90	**69**	**830**	**4,800**	**5**	**Yes**
Technetium-99	**0.07**	**5.63**	**1,800**	**200**	**Yes**
Tin-126	450	0.00373	0.00056	30	No
Thorium-229	18,000	5.82×10^{-5}	2.2×10^{-7}	0.3	No
Thorium-230	18,000	2.55×10^{-6}	9.5×10^{-9}	0.7	No
Thorium-232	310	0.472	0.012	0.6	No
Uranium-233	310	0.0430	0.0093	3	No
Uranium-234	310	0.246	0.053	3	No
Uranium-235	310	0.00436	0.00094	3	No
Uranium-236	310	0.000321	0.000070	3	No
Uranium-238	310	0.0625	0.014	3	No

Bq/L = Becquerel per litre; Bq/g = Becquerel per gram; ml/g = milliliters per gram

(a) Source: CSA N288.1-14, Table G-2, Loam

(b) Treatment targets were used as screening levels to identify those parameters that may require treatment at the WWTP and/or development of a site-specific limit.

(c) Treatment not feasible. Tritium releases will be managed such that tritium concentrations in Perch Creek do not exceed 7,000 Bq/L. This will be accomplished by providing additional containment for high tritium concentration wastes.

Table 3.5.3-2: Non-Radionuclide Constituent Concentrations in Wastewater and Treatment Targets

Constituent	Concentration in Wastewater (mg/L)	Treatment Target[a] (mg/L)	Treatment Required?
Cations			
Aluminum	**0.15**	**0.05**	**Yes**
Arsenic	0.004	0.05	No
Barium	**1.8**	**0.004**	**Yes**
Cadmium	0.003	1.5	No
Calcium	100	0.1	No
Cesium	0.01	116	No
Chromium	0.005	0.02	No
Copper	**0.1**	**0.02**	**Yes**
Iron	**125**	**1.0**	**Yes**
Lead	**0.02**	**0.02**	**Yes**
Magnesium	68	82	No
Manganese	**5.8**	**0.12**	**Yes**
Potassium	26	53	No
Sodium	100	680	No
Strontium	0.1	1.5	No
Zinc	0.2	0.3	No
Anions			
Bicarbonate	660	*	*
Chloride	17	120	No
Fluoride	0.9	*	*
Phosphate	4	5 (as P)	No
Sulfate	270	*	*
Organics/Other			
Acetone (a)	1.2	*	*
Chrysene (a)	**2.2×10^{-5}**	**1.0×10^{-7}**	**Yes**
Dioxin (a)	**2.5×10^{-7}**	**1.0×10^{-8}**	**Yes**
Fluoranthene (a)	**5.3×10^{-5}**	**4.0×10^{-5}**	**Yes**
Furan (a)	1.1×10^{-9}	*	*
PCBs (a)	**8.9×10^{-5}**	**1.0×10^{-6}**	**Yes**
Tannic acid	50	*	*
Tetrachloroethylene (a)	0.034	*	*
Trichloroethylene (a)	0.04	*	*
5-day Biochemical Oxygen Demand	**62**	**20**	**Yes**

mg/L = milligrams per litre

(a) Treatment targets were used as screening levels to identify those parameters that may require treatment at the WWTP and/or development of a site-specific limit.

* = no treatment established in ERA Benchmarks Summary Table

Additional constituents may be identified. Treatment targets for these would be defined as required.

3.5.3.2 Wastewater Treatment Process

The major processes, and other design features of the WWTP are described in the following sections. Process treatment technologies were selected based on a determination of BDATEA.

3.5.3.2.1 Influent Equalization

The influent equalization system is designed to store and equalize wastewater produced at the NSDF site. The system is designed to contain contact stormwater that would be produced from the largest cell of the ECM during two back-to-back, 100-year, 24-hour storm events (2,820 m^3), as well as leachate from closed cells, and impacted wastewater produced from ongoing site operations. Three above-grade, covered tanks each with a capacity of 1,890 m^3 will be installed to provide the required equalization volume. The equalization volume was selected to contain the worst-case contact stormwater flow, as well as provide adequate buffer capacity for ongoing WWTP operations.

Wastewater will be transferred to the equalization tanks from two pumping stations. Double-walled piping with leak detection will be used for transfer of wastewater to and from the equalization tanks for all below-grade transfer piping installed outside of the equalization tank area and WWTP building. The equalization tanks will be installed within a concrete secondary containment area designed to contain 110% of the volume of a single tank.

Each tank will be equipped with level instruments and will include piping and valves to allow the operator to direct influent wastewater to and from the selected tank. Freeze protection will be provided from two of the equalization tanks, since wastewater flows are expected to be lower during cold temperature months due to decreased contact stormwater flows. Three pumps equipped with variable frequency drives will be installed within the WWTP building and will transfer wastewater from the influent equalization tanks to Train 1 and/or Train 2 of the treatment system. Flow meters will measure and totalize the rate of wastewater flow transferred to each treatment train. Each pump will have a wastewater transfer capacity of up to 11.36 m^3/hour, allowing a full equalization system to be emptied in 21 days using a single treatment train, or 10.4 days with both treatment trains on-line.

3.5.3.2.2 Chemical Precipitation

Each treatment train will include two chemical precipitation tanks operated in series (four tanks in total). The chemical precipitation tanks are sized to provide a minimum of 20 minutes of hydraulic detention time at the design flow rate of 11.36 m^3/hour. The detention design was selected based on the detention time provided in the ongoing pilot scale test, plus a margin of safety. Each tank will be equipped with a variable speed mixer to combine the influent wastewater with desired chemicals to convert soluble metals and radionuclides to insoluble precipitates. The tanks will be constructed with open tops to facilitate access to equipment, and sloped bottoms to enhance tank draining and cleaning for inspection. The tanks will be equipped with level instruments for monitoring purposes. Each chemical precipitation tank will also be fitted with a pH probe and controller.

Based on the results of laboratory scale tests and the ongoing pilot scale test, the following chemical storage and feed systems will be provided to deliver chemicals to each chemical precipitation tank:

- ferric chloride;
- sodium sulfide;
- sodium hydroxide;
- sulfuric acid; and,

- powered activated carbon.

Chemical metering pumps, transfer piping, and controls will be provided to allow each chemical to be dosed to either both of the two chemical precipitation tanks in each train.

3.5.3.2.3 Membrane Filtration

Membrane filtration provides nearly complete removal of suspended solids from the chemically-pretreated wastewater. Membrane filtration provides a barrier through which suspended solids cannot pass, effectively eliminating the presence of suspended solids in the filtered effluent. Suspended solids concentrations in membrane filter permeate are expected to be less than 5 milligrams per litre (mg/L). Each membrane filtration treatment train will include a membrane filter feed tank, membrane filter process tank, and membrane filtration skid. The membrane filter feed tanks provides equalization of chemically-precipitated wastewater, and is sized to provide 8 hours of hydraulic retention time at a flow rate of 11.36 m^3/hour.

The membrane filter process tanks are equipped with a level instrument to control process pumping rates and maintain setpoint elevations of wastewater in the tanks. A dedicated level switch will be provided to shut down pumps and prevent tank overflows. A mixer will be provided in each membrane filter feed tank to maintain solids in suspension.

Three membrane filter transfer pumps (two duty, one standby) transfer chemically-pretreated wastewater from the membrane filter feed tanks to the process tanks. Two duty transfer pumps circulate chemically-precipitated wastewater from the process tanks to the membrane filtration systems, where precipitated and suspended solids are filtered from the wastewater. A flow meter measures and totalizes the flow of wastewater to each membrane filtration system. Concentrated solids removed by the membrane filters are returned to the process tanks. Concentrated solids are periodically pumped from the process tanks to the residuals storage and conditioning tanks. Permeate that passes through the membrane filters is transferred through a pH adjustment tank to the polishing treatment process. The membrane filtration system includes pressure gauges to monitor pressure drop across the membrane filters. Turbidity monitors installed in the permeate discharge piping alert the operator of turbidity levels that may signify the breach of a membrane module.

A dedicated clean-in-place system serves each membrane filtration system to provide chemical mixing and recirculation of cleaning chemicals through the membrane filters on a periodic basis (i.e., approximately once per week). Low volumes of additional cleaning chemicals, including sodium hypochlorite for control of biological fouling, and sodium hydroxide for removal of organic material, are also expected to be required for long-term maintenance of membrane flux rates. After cleaning, the spent cleaning solution is either recycled for use during subsequent cleaning cycles, or discharged to the equalization tanks for re-processing through the WWTP.

3.5.3.2.4 Permeate pH Adjustment

The pH of permeate from the membrane filtration process is expected to be elevated, and may need to be reduced prior to subsequent polishing treatment processes. Each treatment train will include a pH adjustment tank and feed tank for the downstream processes.

Filtered water enters each pH adjustment tank and chemicals are added to adjust the wastewater pH, if necessary, to optimize the effectiveness of the downstream processes. Each pH adjustment tank is sized to provide 20 minutes of hydraulic detention time at the design flow rate of 11.36 m^3/hour. Each pH adjustment tank is equipped with a mixer, pH probe and controller, and level instrument.

Filtered wastewater is transferred by gravity from the pH adjustment tanks to the polishing process feed tanks, each sized to provide 8 hours of hydraulic detention time at the design flow rate of 11.36 m^3/hour. The polishing process feed tanks are equipped with level instruments. Three feed pumps transfer wastewater from the polishing process feed tanks to the polishing process vessels. Flow meters measure and totalize the feed flow rate to each polishing process system.

3.5.3.2.5 Granular Activated Carbon

Two granular activated carbon (GAC) vessels provide removal of organic chemicals that may be present in the wastewater. Each GAC vessel contains 2,000 pounds of granular activated carbon for adsorption of COPC. When the GAC in the lead vessel reaches its capacity to adsorb COPC, the GAC is replaced with fresh media, or the entire GAC vessel is exchanged for a new vessel containing fresh media. Pressure gauges monitor the pressure drop across each GAC vessel.

3.5.3.2.6 Ion Exchange

The ion exchange process provides polishing treatment for removal of low concentrations of metals and radionuclides that remain after chemical precipitation and membrane filtration. The results of the ongoing pilot scale test illustrate that strong acid cation exchange resin can remove heavy metals and radionuclide surrogates such as strontium to very low concentrations, in many cases below detection limit. Zeolite resin was demonstrated to be effective for removal of cesium. Ion exchange was demonstrated to achieve lower effluent concentrations of cesium than reverse osmosis technology during the laboratory scale tests, and achieved lower concentrations of strontium and cesium compared to reverse osmosis technology during the ongoing pilot scale test. Resin capacity was shown to be greater during the ongoing pilot scale test compared to the laboratory scale tests. It should be noted that concentrations of strontium and cesium in the pilot scale test wastewater simulant are several orders of magnitude higher than that expected in the full-scale WWTP wastewater.

Each ion exchange treatment train includes a series of ion exchange vessels to remove the range of constituents expected to be present in the wastewater. Each ion exchange vessel contains resin specific to the COPC to be removed from the wastewater. Pressure gauges monitor the pressure drop across each ion exchange vessel.

3.5.3.2.7 Final pH Adjustment

Effluent from the ion exchange vessels is conveyed by residual pressure to the final pH adjustment tanks. The final pH adjustment tanks are sized and equipped in an identical manner to the initial polishing system pH adjustment tanks, and are used to control the pH of the final effluent to within an acceptable range for discharge. Chemicals are metered into the tanks to adjust the final effluent pH, if necessary, to comply with discharge requirements. Each pH adjustment tank is sized to provide 20 minutes of hydraulic detention time at the design flow rate of 11.36 m^3/hour.

3.5.3.2.8 Final Effluent Storage

Treated effluent from the final pH adjustment tanks is conveyed by gravity to the final effluent storage tanks, each sized for 8 hours of hydraulic detention time at the design flow rate of 11.36 m^3/hour. The final effluent storage tanks provide storage of final effluent for sampling prior to discharge. Each tank is equipped with level instruments to measure and monitor the elevation of final effluent in the tank, as well as to alarm the tank high-high level. Effluent samplers provide for automatic collection of composite samples to document wastewater discharge characteristics. Flow meters measure and totalize the final effluent that is discharged from the WWTP.

3.5.3.2.9 Residuals Storage and Dewatering

Based on the projected wastewater quantity and characteristics, and results of pilot scale tests, it is estimated that an average of approximately 1 to 2 m^3/day of liquid residuals will be produced from the chemical precipitation and membrane filtration process, with a solids concentration ranging from 15,000 to 50,000 mg/L. Two pumps transfer residuals from the membrane filtration system process tanks to the residuals storage and conditioning tanks. Each tank has a capacity of approximately 80 m^3. Each tank is equipped with a mixer, level instruments, and decant ports. The mixers are used to blend conditioning chemicals with the residuals, if needed, to enhance dewaterability. Decant ports will be provided to decant supernatant from the tanks, if additional settling of solids occurs in the tanks. Removal of supernatant from the storage and conditioning tanks will result in higher residuals concentrations and improved dewaterability. Supernatant will be directed to the influent equalization tanks.

Two filter press feed pumps transfer residuals from the residuals storage tanks to a recessed chamber filter press for dewatering. The filter press dewatering operation is a batch process, consisting of filling the press with residuals for dewatering, building pressure to complete the dewatering process, and opening the press to allow dewatered residuals to be removed. Dewatered residuals will be transported to the ECM for disposal.

3.5.3.2.10 Chemical Storage and Metering

Chemicals will be stored in a dedicated area of the WWTP within containment areas suitable for each particular chemical. Liquid chemicals will be stored in bulk storage tanks sized to provide a minimum of four months of storage capacity. Two bulk storage tanks, each with capacity of 1,000 gallons will be provided for the following liquid chemicals:

- ferric chloride (35% solution as $FeCl_3$);
- sodium sulfide (15% solution as Na_2S);
- sodium hydroxide (50% solution as NaOH); and,
- sulfuric acid (98% solution as H_2SO_4)

A chemical metering pump is provided for each chemical dosing location; in addition, a standby spare pump will be provided for each pump type and size to allow for quick replacement of any pump, if necessary.

3.5.3.2.11 Residuals Handling and Disposal in the ECM

The criteria for disposal of waste in the ECM are defined in WAC. Two types of residuals will be produced by the WWTP: dewatered residuals produced by the chemical precipitation process, and spent media from the GAC and ion exchange processes. Based upon the projected wastewater quantity and characteristics, and results of laboratory and pilot scale tests, the annual quantity of dewatered residuals is expected to be approximately 13 m^3/year, and the annual quantity of spent GAC and ion exchange resin is expected to be approximately 17.5 and 22 m^3/year, respectively. The level of radionuclides in the dewatered residuals and spent GAC and ion exchange resin is expected to be well below the definition of low level radioactive waste, and is acceptable for disposal in the ECM without containment or packaging.

Waste disposed in the ECM must not contain free liquids in excess of 1% of the waste volume. Results of pilot scale testing demonstrate that residuals produced from chemical precipitation can be dewatered to a solids content acceptable for disposal in the ECM. Spent GAC and ion exchange resin may contain free liquid in the filter vessels. In order to dispose the vessels containing spent media directly in the ECM, the free liquid will be removed and

void spaces in the vessel will be grouted. Alternately, spent media can be removed from the vessel using water to slurry the media into a container for dewatering. Water removed from the media will be discharged to the equalization tanks for re-processing. After free water has drained from the media, the geomembrane with spent media can be disposed in the ECM. The expected characteristics of dewatered residuals and spent GAC and ion exchange resin as described above indicate these wastes can be disposed in the ECM without additional treatment or containment.

3.5.4 Site Infrastructure and Support Facilities

The design of the site infrastructure and support facilities will accommodate year-round operation during the NSDF Project construction and operations, and for the long-term monitoring and maintenance activities during the closure and post-closure phases.

3.5.4.1 Site Infrastructure

3.5.4.1.1 Access Roads

The NSDF site transportation network consists of primary and secondary access roads. Primary access roads facilitate two-way traffic to the site. Secondary access roads facilitate both one- and two-way traffic on the site. There are two primary access roads to the site (Figure 3.1.1-1). The primary waste shipment access roadway is from the Dump Road/East Mattawa Road intersection south of the NSDF site boundary. This road is proposed to be comprised of a granular pavement structure. This roadway is to be used for waste shipments arriving to the NSDF site, as well as transport vehicles leaving the NSDF site, providing that vehicle decontamination is not required.

The second primary access route to the NSDF site is from Plant Road to the site boundary. This roadway is proposed to be comprised of an asphalt pavement structure from the Plant Road to the site boundary to limit dust generation in the vicinity of Plant Road, the primary access roadway into the CRL main campus. A right-turn/deceleration lane is proposed at the intersection with Plant Road to allow for slower moving vehicles to turn into the site without impeding eastbound traffic to the CRL main campus. The second primary access roadway will be used for occasional waste deliveries to the NSDF site, but it primarily dedicated for employee access to the support facility buildings, as well as material and equipment deliveries to the site.

Secondary site access roadways generally consist of perimeter roads around the ECM as well as the WWTP. The secondary roadways are proposed with granular pavement structures and are sized to facilitate two-way vehicular traffic around the site. Decon Road, linking the ECM to the vehicle decontamination facility, is proposed as an asphalt roadway and will be used by waste shipment vehicles or equipment that require decontamination.

Portable traffic barriers are proposed for the operational phase of the ECM to limit the interaction of potentially contaminated vehicles with routes designated for uncontaminated vehicles and pedestrians.

3.5.4.1.2 Site Security

The NSDF Project site security follows CRL's site security requirements and physical security plans. Access to the NSDF Project site is exclusively from within the CRL property boundary and access to the CRL property is strictly controlled by security personnel. In addition, a security fence installed around the entire perimeter of the NSDF site will prohibit unauthorized personnel from entering, and limit animal injury and contact during construction and waste placement operations. Fencing is anticipated to be chain-linked and include a below-ground portion to

prevent entry of turtle species. Entrance gates with security features located at the NSDF site's north and south entrances will control access to and within the site.

3.5.4.1.3 Site and Worker Parking

Site and worker parking will be positioned near the administration office and the vehicle decontamination facility. This area will be large enough to accommodate vehicles from on-site personnel, visitors, and CNL site security. Parking areas will be constructed of granular material.

3.5.4.1.4 Laydown and Stockpile Area

Laydown and stockpile areas are established both within and outside of the ECM footprint to support waste placement operations in accordance with the ECM and support facility development, landfill sequencing, and design plans. The laydown areas are large enough to accommodate cell construction and waste operations including adequate space for haul vehicles and waste loading equipment to operate. The stockpile areas are large enough to store overburden during construction and to stage soil used for cover purposes.

As the ECM is developed sequentially, undeveloped cells may be prepared and used as stockpile areas to store overburden soils to be used during construction or for daily/interim cover stockpiles. This approach reduces the required area for the laydown and stockpile of materials.

3.5.4.1.5 Drum and Waste Unloading Platforms

The drum and waste unloading platforms are included within the ECM footprint in the temporary storage and waste receiving and processing area. The platform will be constructed at grade and will consist of aggregate material provided to minimize dust generation and facilitate contamination control. The platform will incorporate the use of dedicated drum placement vehicles to transfer drummed wastes inside the NSDF cell waste placement area. The waste unloading platform design will facilitate the safe and efficient unloading of solid waste from site waste hauling trucks. Drum and waste unloading platforms will also be designed to accommodate year-round operation.

3.5.4.1.6 Sanitary Sewage Conveyance System

The NSDF's sanitary conveyance system has been designed to convey the peak sewage flows generated by up to 45 full time employees at the NSDF site. The sanitary system uses a network of gravity sewers to convey septage from the vehicle decontamination facility, the operations support center, the administration office building, the north kiosk, and the WWTP to a sanitary pumping station located near the staff operations center. The sanitary pumping station transfers the collected septage which discharges to a second gravity sewer network. The second gravity sewer terminates near the NSDF's south site entrance and will tie into the gravity sewer which is currently being developed as part of the Emergency Route #3 Relocation Project.

The sanitary gravity sewers were designed to yield a mean flow velocity, when flowing at full capacity, of not less than 0.6 m/s. Allowances were made for hydraulic losses at sewer manholes as per the MOE for sewage system design guidelines. Frost protection was provided by maintaining a burial depth greater than the calculated frost penetration depth. The sanitary sewers were designed to flow at a maximum of 65% capacity for the first run out from buildings and at a maximum of 80% capacity elsewhere on site.

3.5.4.1.7 Contact Water Conveyance System

The NSDF's contact water conveyance system has been designed to convey the peak contact water flow rates generated at the NSDF site. The contact water conveyance system is comprised of gravity sewers and two

pumping stations. Sources of contact water at the NSDF site include the ECM (generates leachate and contact stormwater), the vehicle decontamination facility (generates decontamination wash water), the operations support center (generates decontamination wash water) and the WWTP (process related drains). Contact water is conveyed by gravity sewer to a contact water pump station, which then pumps it to the WWTP's equalization tanks for eventual treatment.

The pumping stations are both cylindrical HDPE structures that house three submersible pumps each. The structures are provided dual containment by means of installing a 2,400 mm diameter cylindrical tank (carrier wall) inside of a 3,000 mm diameter cylindrical tank (containment wall). A leak detection system is installed between the two structures, between the carrier wall and containment wall. If the leak detection system detects moisture, an alarm is generated and the tanks will be inspected. The valves were located in valve chambers to limit the pumping station's size and to improve the serviceability of valves. The valve chamber is also alarmed with a leak detection system.

Three HDPE pressure mains exit the contact water pumping stations and enter the nearby valve chamber. The three pressure mains interconnect in the valve chamber and only two pressure mains exit. The pressure mains use a pipe in a pipe approach to provide dual containment. The pressure main is sloped such that a leak would be conveyed back to the pump station. The pumping station is supplied with backup power for contingency. Alarms and emergency shutoff measures will be setup at the pumping station prevent overflow at the pumping station.

The contact water gravity sewers use a similar approach as the pumping stations for achieving dual containment. The HDPE pipe was selected for its ability to be welded (which greatly reduces the number of couplings that are often the source of leaks), for its long service life, and its corrosion resistance. Frost protection was provided by maintaining a burial depth greater than the calculated frost penetration depth.

3.5.4.1.8 WWTP Treated Effluent Conveyance System

The NSDF's WWTP treated effluent conveyance system is designed to convey the peak flow generated by the WWTP. The treated effluent system uses gravity sewers to convey the treated effluent from the WWTP to a discharge location (see Figure 3.1.1-1). Sampling provisions are provided at the point of discharge. The sampling station uses a watertight maintenance hole with a raised inlet for the purposes of obtaining samples.

The treated effluent sewer is designed to yield a mean flow velocity, when flowing at full capacity, of not less than 0.6 metres per second (m/s). Allowances were made for hydraulic losses at sewer manholes as per the MOECC sewage system design guidelines. The sewer was designed to flow at a maximum of 65% capacity for the first run out from the WWTP and at a maximum of 80% capacity elsewhere on site. The peak flow rate of the treated effluent from the WWTP is determined by the WWTP's treatment capacity. The proposed WWTP will have two treatment trains each with a treatment capacity of 0.126 to 3.155 litres per second (L/s). The WWTP's treated effluent conveyance system will therefore be sized to convey the WWTP's peak treatment capacity of 6.310 L/s.

The system's outlet uses a headwall that discharges to a level spreader for the purposes of preventing erosion and sedimentation at the outlet. An exfiltration gallery is proposed at the discharge outlet to promote the exfiltration of treated water into the local groundwater regime.

3.5.4.1.9 Utilities

The following site utilities will be required to facilitate the NSDF Project construction, and operation and maintenance:

- potable water service for human consumption and staff decontamination facilities;
- service water for vehicle decontamination facilities, and WWTP operations if required;
- electricity for site facilities for lighting; venting and air conditioning; and other power uses;
- natural gas for heating; and,
- telephone and internet access for communication and CNL surveillance equipment (such as security cameras).

The water distribution system is designed to supply water to meet the potable and fire protection water demands at the NSDF site, as well as supply and maintain sufficient pressures to meet the NSDF's operational requirements. The NSDF's watermain will tie into a watermain which is currently being designed as a part of the Emergency Route #3 Relocation Project.

Fire protection at the NSDF site is provided through fire hydrants connected to the combined service watermain. The vehicle decontamination facility and WWTP are supplied with secondary feedlines to meet each building's sprinkler systems' demands. All of the buildings and facilities, including the kiosks will be provided with potable water service. All watermains are equipped with cathodic protection on all metal appurtenances; cathodic protection monitoring stations and tracer wire are supplied. The watermain has been provided frost protection by locating it below the frost line.

3.5.4.2 Support Facilities

The NSDF Project will require various facilities both during construction, and operation and maintenance. The facilities makeup will consist of both modular and permanent structures with associated construction features required for their use or installation. Support facilities will be designed for year-round operation.

3.5.4.2.1 Wastewater Treatment Building

The WWTP building provides a controlled enclosure within which the process systems will be located. The main processing areas is split into a chemical tank room, dry chemical storage room, pre-treatment, residues management, decontamination shower/change room, PAC room and maintenance areas. Connected to the side of the treatment process area is a WWTP maintenance shop, which will be used to store spare parts and facilitate maintenance activities.

3.5.4.2.2 North and South Kiosks

The NSDF site will have two weigh scales, one on the north and one on the south (Figure 3.1.1-1). The south kiosk will be used for the majority of incoming loaded waste transport vehicles for both loaded weight and tare weight. The north kiosk will be used by the trucks coming from Plant Road for loaded weight and tare weight, and by any waste transport vehicles found dirty upon scanning for tare weight after passing through the vehicle decontamination facility. A kiosk will be located at each scale with computerized waste quantity tracking equipment. After unloading the waste, the waste transport vehicles will be scanned and decontaminated, if necessary.

3.5.4.2.3 Administration Building

The administration building is positioned off the main site access road. It will serve dedicated NSDF Project site personnel (non-construction workers) during construction, as well as operation and maintenance. The administration building includes office space, a meeting room, a records room, a washroom facility and a lunch room. The administration building will also include necessary minimum first aid equipment, per CNL Health and Safety program and Ontario Labour Code requirements.

3.5.4.2.4 Operation Support Centre

The operations support centre building includes the necessary spaces required for the decontamination of the personnel working on-site and shower facilities after work. The building is designed to provide dirty and clean change rooms and decontamination shower, in addition to general change rooms and washroom facilities for site personnel. Service rooms for the facility (e.g., mechanical, electrical, janitorial and storage) are located outside of the contaminated zone. This facility will also house secondary first aid equipment to provide quick access for workers requiring decontamination.

3.5.4.2.5 Vehicle Decontamination Facility

The vehicle decontamination facility provide equipment and facilities for appropriate decontamination of site and off-site vehicles and vehicle light maintenance; these two spaces are completely separated from each other to prevent contamination. Only vehicles that have come into contact with contamination will need to pass through the vehicle decontamination facility. The facility is sized to accommodate the decontamination of on-site vehicles and highway-legal vehicles. The facility will include decontamination equipment like high-pressure water wash equipment with a wash water collection system. The decontamination system will be designed to limit water use and allow for on-site treatment of wash water at the WWTP. The maintenance shop will be designed to accommodate the on-site servicing of equipment, and to house necessary on-site machinery, tools, and miscellaneous industrial chemicals. Site vehicles to be maintained include loaders, compactors, drum placement vehicles used during the operation of the NSDF Project. The vehicle decontamination facility will be enclosed, as NSDF Project waste placement activities are required to occur year-round.

A fueling area for on-site vehicles will be positioned in a convenient location away from all facilities. Fueling will be provided by a small packaged tank and pump. The fueling area will be designed to protect the natural environment from fuel-related spills.

3.6 Operations Phase

During the operations phase, the new facilities constructed will be commissioned and operated to the end of 2070. The Operations phase includes the transport of waste on-site to the ECM, placement of wastes in the ECM, covering of disposal cells once filled, treatment of wastewater in the WWTP, and operation of associated infrastructure and support facilities. Equipment required during the operations phase is shown in Table 3.6-1.

Table 3.6-1: Estimated Typical Equipment Required During the Operations Phase

Equipment	Estimated Quantity (units per day)
Trucks in the Active Landfill (shuttling full waste containers)	3
Dump Trucks (delivering waste to ECM)	10
Forklifts	2
Water Trucks	2
Track hoes	2
Bulldozer	3
Grader	1
Crane	1
Vehicles	10
Miscellaneous, for example: ■ Pumps, large, centrifugal ■ Pumps, small, diaphragm ■ Pumps, submersible ■ Portable Generators ■ Air Compressors ■ Light Plants ■ Snow Removal Equipment	Various

Assumes operations involves working in one disposal cell at a time.

The following sections describe activities related to the operations phase for the ECM and WWTP.

3.6.1 Engineered Containment Mound

3.6.1.1 Waste Profiling, Acceptance and Verification Process

3.6.1.1.1 Waste Profiling Process

The CNL Waste Programs and Waste Operations teams will have a qualified Waste Acceptance team to review the generator's waste processes, profile and operations in order to approve waste for emplacement into the ECM. All waste is the responsibility of the generator until it has been accepted by the Waste Operations (designated facility authority) for placement and subsequent disposal. In general, waste acceptance will include verifying that waste meets requirements, has been appropriately transported to the ECM, and is ready for emplacement. All waste accepted at the NSDF must be profiled prior to disposal. Profiling the waste material contents includes the following information, activities, and documentation to support and validate the waste profiling process:

- radiation surveys;
- analytical chemical and physical sampling and testing;
- measurements of chemical and physical properties associated with waste constituents; and,
- testing of bulk soil and soil-like waste for designated properties associated with disposal cell stability and performance.

The monitoring, sampling, testing, and measurements associated with the characterization of a given waste stream will be documented in the Waste Profile. The Waste Profile serves the following functions:

- enables the evaluation of wastes for acceptance and performance in the NSDF;
- maintains an operating record of waste material shipments including receipt, acceptance, storage, and disposal;
- provides a historical record of each waste stream; and,
- ensures compliance with CRL's licence and regulations.

The waste profiling process consists of the following steps:

- waste characterization;
- Waste Profile Record completion and submittal;
- Waste Profile review and approval by the waste acceptance team; and,
- notice of approval to transport to the NSDF.

Initial discussions between the waste generator and the Waste Acceptance team regarding the waste are essential to ensure that the waste profiling process is accurate, meets NSDF requirements, and is complete.

3.6.1.1.2 Waste Acceptance Process

Early in the waste acceptance process, the generator is required to sample waste, where applicable, to accumulate analytical data on each waste stream. The waste generator must determine the physical and chemical characteristics of the waste with sufficient accuracy and detail to provide proper designation and management of such waste. This includes, but is not limited to, sufficient knowledge to demonstrate that the waste is not prohibited from disposal at the ECM, segregating and confirming compatibility of waste with containers or transport package, and confirming that the waste can be safely disposed. This must be determined in accordance with specified WAC requirements, criteria, and applicable regulations. This information is then used to complete the Radioactive Waste Profile Record.

Canadian Nuclear Laboratories must maintain information for all wastes being managed. As such, the "profile" provides information in the following areas:

- generator and waste stream information;
- radiological information;
- chemical composition and hazard evaluation; and,
- physical properties and packaging.

3.6.1.1.3 Waste Verification Process

Waste verification will be completed through a variety of activities, including but not limited to:

- an initial paper verification (e.g., comparison that submitted waste inventory documentation meets established WAC, piece count);
- trained and qualified Waste Acceptance team to oversee the waste packaging or the waste generation processes;
- routine assessments of wastes at waste project or operating facility locations to both assess the wastes and to assist the generator in meeting the WAC; and,
- random assays of wastes accepted at the ECM (e.g., assays can vary from simple dose rate measurements to more complex non-destructive alpha/gamma analyses) to confirm that the contents meet the submitted documentation and to provide worker and public safety.

A portion or all of these types of activities will be assessed and implemented, as appropriate, to provide an optimal verifiable audit process.

3.6.1.2 Waste Placement

The NSDF consists of ten disposal cells, each designed for progressive construction, filling, and closure in sequence. Dividing the entire NSDF disposal area into ten cells provides for the preferred operation and closure sequence for each cell.

3.6.1.2.1 Waste Placement Objectives

Waste placement activities are completed in a manner that protects and maintains the integrity of the liner system, the leachate collection system, final cover system, and all NSDF ancillary features and equipment. The following are objectives for waste placement.

- Waste handling, from receipt at the NSDF to final placement, is limited to mitigate the potential for dust generation and exposure to workers and the environment.
- When possible, wastes with higher dose rates are placed in the lower portions of the disposal cells and covered with waste having lower dose rates or fill materials to provide shielding from radiation. The design allows for 0.8 m of granular material on top of the primary liner to protect against radiation doses to the liner.
- Regardless of placement location, all waste exhibiting high dose rates is placed and immediately covered with waste having lower dose rates or fill material to maintain doses to ECM workers ALARA.
- Where possible, higher activity waste is placed in the bottom of the disposal cells and covered with bulk LLW material to provide shielding against radiation. The higher activity waste may also be placed in segregated areas for handling and disposal. Again, the design allows for 0.8 m of granular material on top of the primary liner to protect against radiation doses to the liner.
- Waste is placed to maximize its in-place density and reduce void space to limit the potential for future settlement of the waste.

- As waste is placed into the disposal cells, the surface of the waste is maintained at a minimum 2% slope to promote run-off and minimize infiltration of surface water into the waste.
- Waste placement is conducted to minimize the time that on-site workers are required to work directly on the LLW working (disposal) face in accordance with ALARA principles.
- The waste placement sequence is conducted in a manner that provides flexibility in final side slopes and mound for waste disposal.
- Waste placement is designed to accommodate expected variations in the waste mix (relative percentages of the various waste types) and delivery times for waste arriving for placement.

3.6.1.2.2 General Waste Placement Criteria

The following general criteria are applied for waste placement activities to prevent differential settlement and maintain ALARA conditions during operations.

- Waste placement will allow for specified areas where different waste types can be disposed of while limiting the vertical height of the column of each type of waste (e.g., operational lift); this is intended to ensure that adjacent columns of waste exhibit the same potential for long-term settlement.
- Waste placement will not allow for any column of waste (cell floor to cover) to be made up of only one type of waste (packaged waste, soil, grouted debris, etc.); this is intended to prevent differential settlement.
- Waste placement will allow for placement of waste exhibiting high radiation levels only on a scheduled basis to maintain ALARA conditions associated with cell operations.
- Waste placement will allow for receipt and placement of waste exhibiting high radiation levels only if there is sufficient lower radiation level waste already in the vicinity where the high radiation waste will be placed that can be used to shield workers from higher radiation levels in accordance with ALARA principles. Remote handling will be required for waste shipments registering 2 mSv/hour or above and will be immediately grouted in place or covered with daily cover soil in order to limit the radiation and protect the operators.

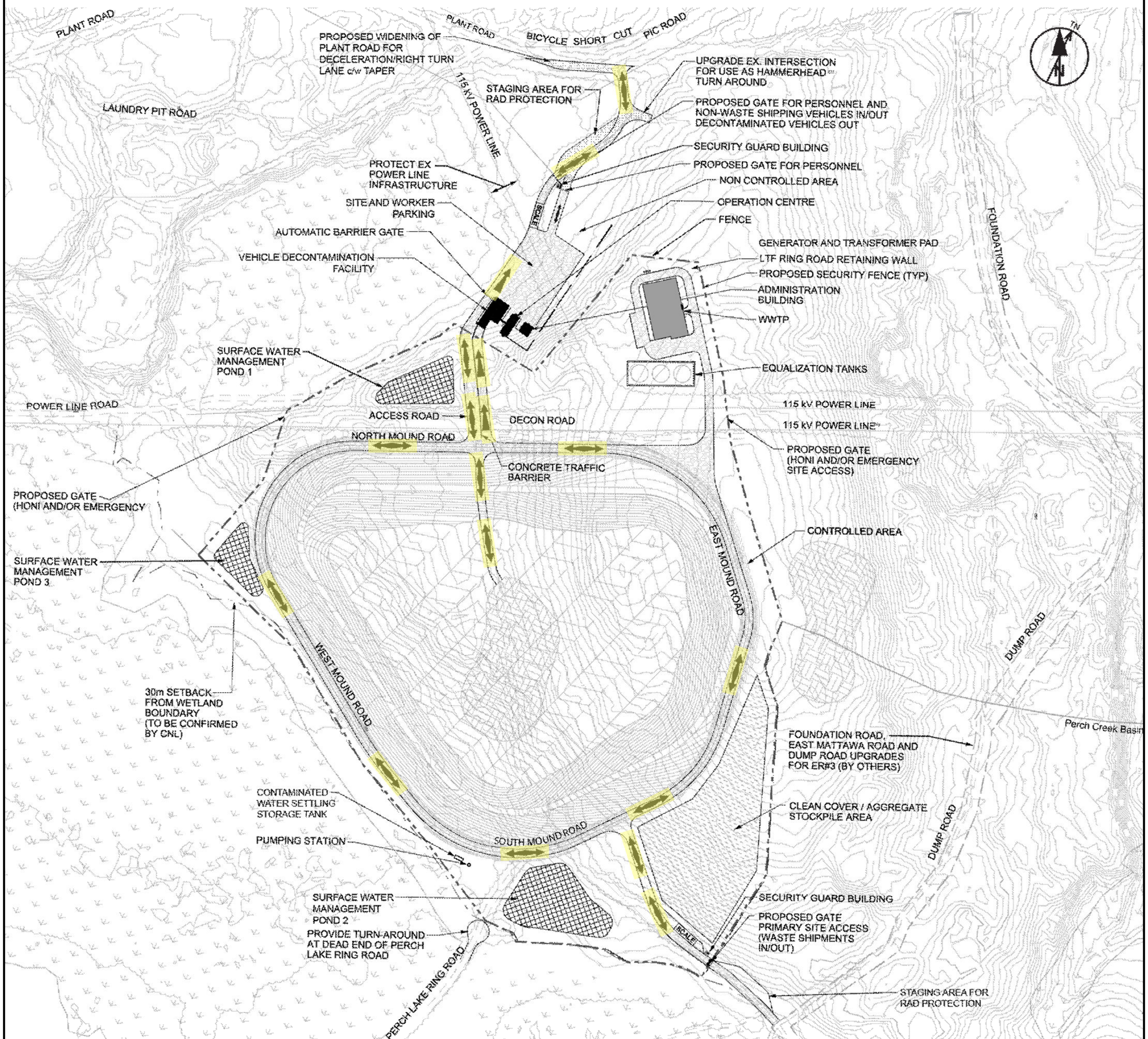
3.6.1.2.3 Transportation of Waste

The waste to be placed in the ECM will primarily originate from operations and decommissioning activities at the CRL property, including legacy radioactive wastes currently stored on site, those from future operations, those which will be generated from the demolition and decommissioning of structures at CRL, and the remediation of some contaminated areas at CRL through to 2070. A few percent of the waste to be placed in the ECM will be from off-site sources (e.g., Whiteshell Laboratories, commercial sources such as hospitals and universities).

Waste haul vehicles used to transfer waste to the ECM will vary based on the conveyance form (e.g., packaged or bulk waste). For example, bulk debris or soils may range from standard tandem dump trucks (8 m^3 capacity) to highway semi-dump trailers (approximately 20 m^3 capacity). On-site transportation of waste will be in accordance with the *Packaging and Transport of Nuclear Substances Regulations, 2015* and *Transportation of Dangerous Goods Regulations* as found in the site Licence Conditions handbook requirements, and other guidance as specified in the IAEA *Regulations for Safe Transport of Radioactive Material* (IAEA 2012), and CNSC's guidance document *Radiation Protection Program Design for the Transport of Nuclear Substances* (CNSC 2012).

Off-site transportation of waste will also be completed in accordance with these regulations; although this is not considered in the scope of the NSDF Project.

The transportation plan (Figure 3.6.1-1) for Stage 1 of the ECM involves transport vehicles entering the ECM from the south. Waste transport vehicles coming from the south will be weighted at the south kiosk and then will unload the waste into active cells (Cells 1, 2 or 3). After unloading, the vehicles will be scanned for radiation in a clean area of the ECM. Clean vehicles will exist the ECM to the south; contaminated vehicles will be routed to north to the vehicle decontamination facility. Waste transport vehicles will continue to the north or south kiosk to be weighted prior to leaving the site. After the first three cells are filled, the berm on the south side of the ECM will be constructed. Once this berm is constructed, the access to the ECM on the south will be closed. The only entrance into the ECM will be from the north. Waste transport vehicles entering the NSDF from the Dump Road on the south will travel west on perimeter road, and enter the ECM on the north. In addition, some transport vehicles may enter the site from the north via Plant Road. After unloading, the vehicles will follow the same scanning and exit procedures as described above.



REFERENCE(S)
1. FIGURE OBTAINED FROM B1550-505240-PLA-001 DELIVERABLE 14.2, REVISION B

CLIENT
CANADIAN NUCLEAR LABORATORIES

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT

TITLE
TRANSPORTATION PLAN

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	MM
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0004	0.0	3.6.1-1

S:\Clients\Canadian_Nuclear_Laboratories\NSDF\99_PROJ\1547525_NSDF_EIS\40_PROD\0004_EIS_SectionThree\1547525-0004-G-0005.mxd

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:
25mm
0

3.6.1.2.4 Waste Placement Equipment

Front wheel loaders or similar vehicles are operated at the waste loading platforms to load the waste into the haul vehicles. The waste placement equipment used will depend on the types and quantities of wastes to be placed in the ECM. Methods of placement will include: 1) the use of dedicated haul vehicles to transfer bulk waste directly into the cells, spread by bulldozers or other heavy equipment, and compacted by rollers or other compactors, or 2) the use of heavy equipment to offload and place waste components or containers directly into the cells.

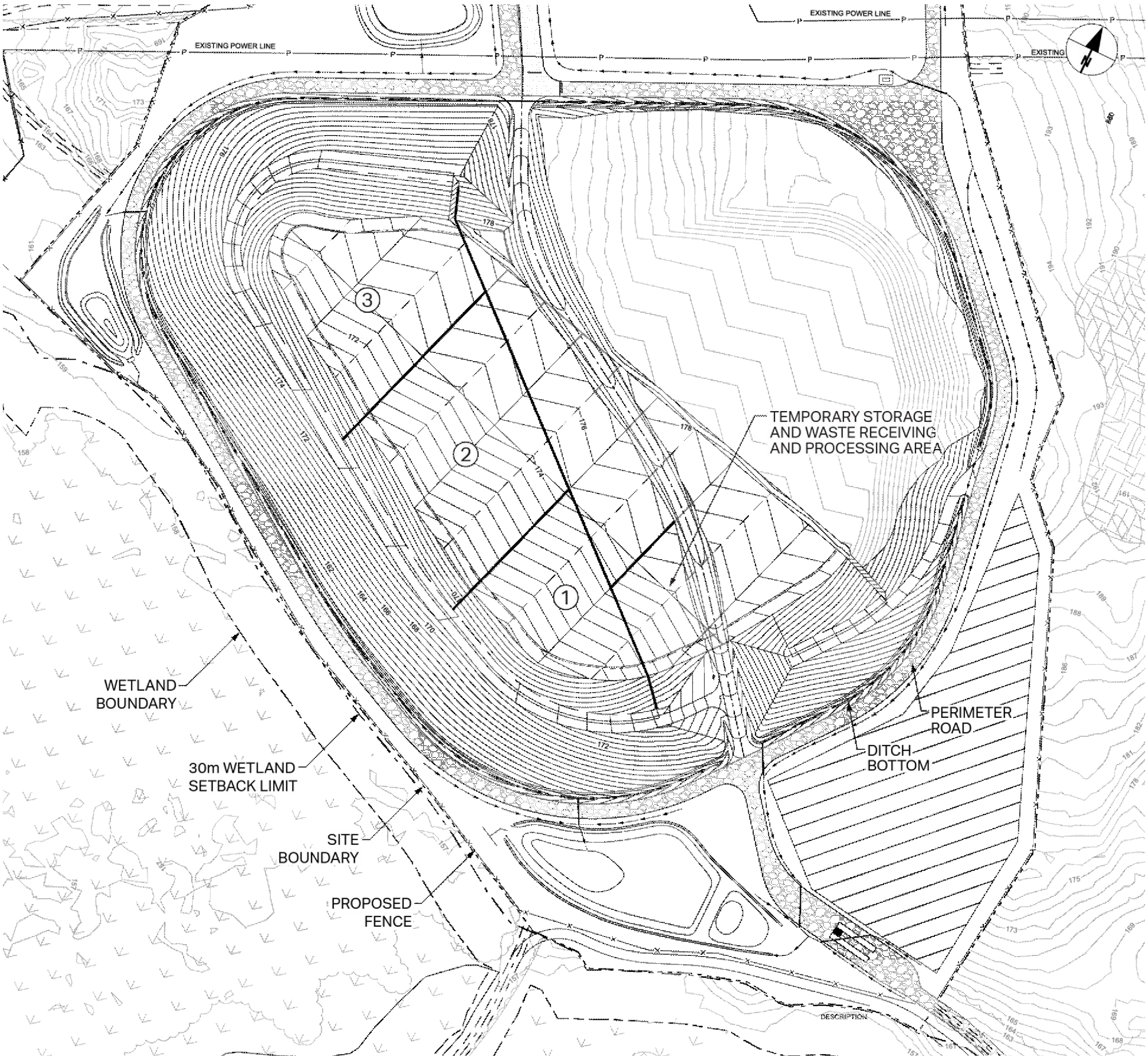
Waste would be placed in the active cell in the ECM through use of dedicated equipment that is meant to operate in contaminated areas. The use of dedicated waste placement equipment includes haul vehicles, cranes, bulldozers, compaction equipment, and other heavy equipment. Dumping of waste would typically be from a clean dump ramp. Dedicated equipment (such as a bulldozer) within the cell would spread and compact the waste. This method also limits the potential for contamination of equipment used to transport waste from the generating sites.

Compaction equipment may include soil compactors, sheepsfoot rollers, or similar heavy equipment for Type 1, soil and soil-like waste, and Type 3, non-soil-like waste. A landfill compactor (similar to a Caterpillar 826) may be used for compaction of Type 2, comingled radioactive waste, if the waste is highly variable (heterogeneous) or contains large amounts of refuse or debris waste. Other heavy equipment that may be used for waste placement may include an excavator for bulk waste material and a crane or forklift for placing waste containers, large debris components, and waste packages with high dose rates. Water trucks are used for moisture adjustment and dust control.

3.6.1.2.5 Disposal Cell Sequencing

The waste placement in the ECM will begin after construction of the berm and floor of Stage 1 (i.e., 525,000 m^3 of waste). The temporary storage and waste receiving and processing area for cells 1, 2, and 3 is shown in Figure 3.6.1-2, and a similar temporary storage and waste receiving and processing area will be constructed for subsequent cells. Waste will be placed in each cell as described in Section 3.6.1.2.6. Toward the end of the cell 3 waste placement, the notch in the south berm will be closed to allow for the filling of cells 4, 5, and 6. This will allow the disposal of 525,000 m^3 of waste and will complete Stage 1 of the ECM (Figure 3.6.1-3). The notch will be left in the mound at the location of the existing East Mattawa Road on the north, so that waste transport vehicles can enter and exit the mound at floor level, eliminating the need for ramps.

As waste disposal commences in the small Cell 6 of Stage 1, construction will start on the remainder of the containment berm and the floor system for Stage 2 (i.e., 1,000,000 m^3 of waste; see Figure 3.6.1-4). The waste placement sequencing would continue for all ten cells. The same notch will be left in the mound, so that waste transport vehicles can enter and exit the mound at floor level, eliminating the need for ramps.



CLIENT
CANADIAN NUCLEAR LABORATORIES

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT

TITLE
STAGE 1 PLAN WITH TEMPORARY STORAGE AND WASTE RECEIVING AND PROCESSING AREA

CONSULTANT

Golder Associates

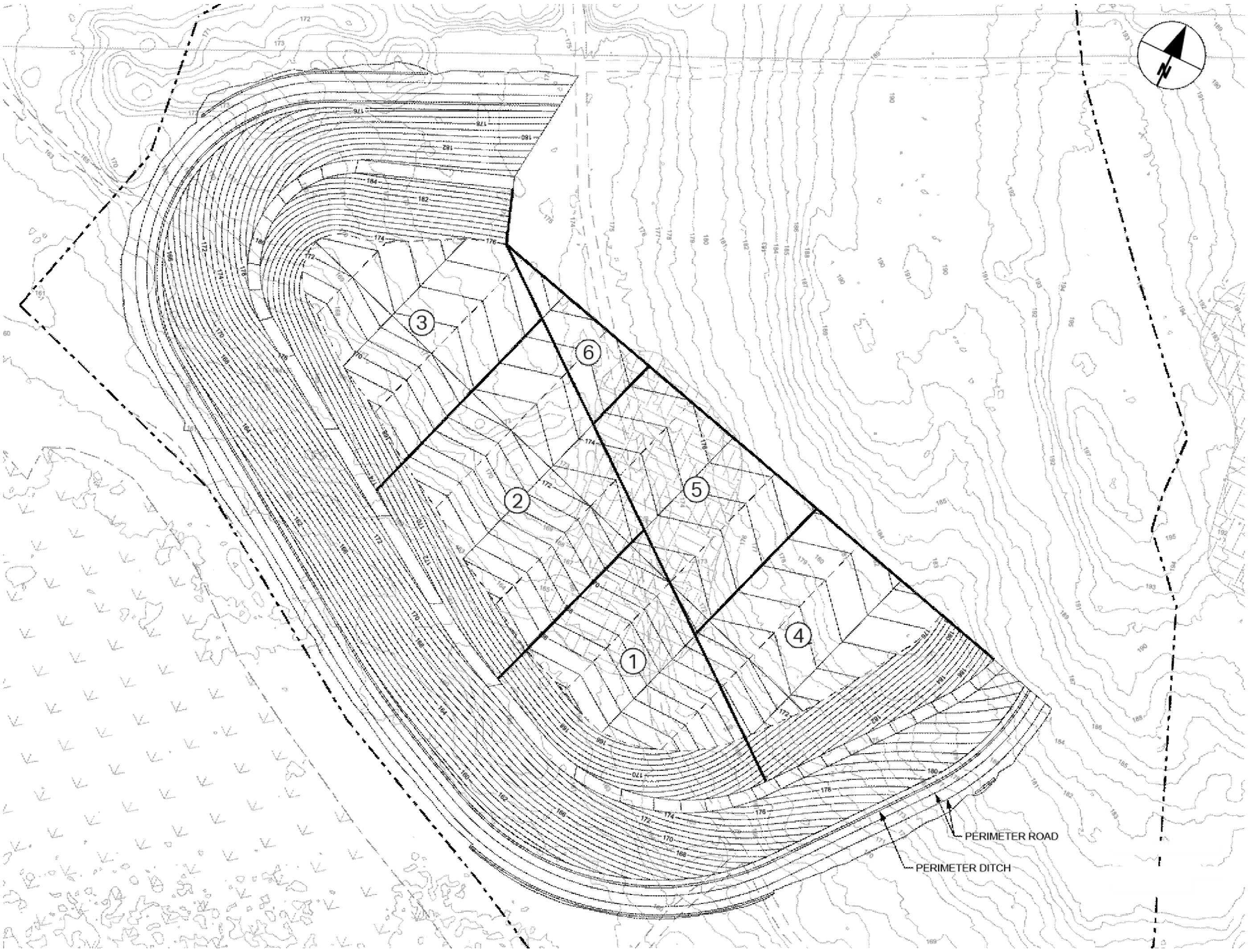
YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	MM
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0004	0.0	3.6.1-2

REFERENCE(S)
1. FIGURE OBTAINED FROM B1550-505240-PLA-001 DELIVERABLE 14.2, REVISION B

S:\Clients\Canadian_Nuclear_Laboratories\NSDF\99_PROJ\1547525_NSDF_EIS\40_PROD\0004_EIS_Section_3\1547525-0004-G-0004.mxd

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm 0



CLIENT
CANADIAN NUCLEAR LABORATORIES

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT

TITLE
STAGE 1 CELLS AND SEQUENCING PLAN

CONSULTANT

Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	MM
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0004	0.0	3.6.1-3

REFERENCE(S)
1. FIGURE OBTAINED FROM B1550-505240-PLA-001 DELIVERABLE 14.2, REVISION B

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:
25mm
0

S:\Clients\Canadian_Nuclear_Laboratories\NSDF\99_PROJ\1547525_NSDF_EIS\40_PROD\0004_EIS_Section_3\1547525-0004-G-0005.mxd

REFERENCE(S)
1. FIGURE OBTAINED FROM B1550-505240-PLA-001 DELIVERABLE 14.2, REVISION B

CLIENT
CANADIAN NUCLEAR LABORATORIES

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT

TITLE
STAGE 2 CELLS AND SEQUENCING PLAN

CONSULTANT

Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	MM
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0004	0.0	3.6.1-4

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm

S:\Clients\Canadian_Nuclear_Laboratories\NSDF\99_PROJ\1547525_NSDF_EIS\40_PROD\0004_EIS_SectionThree\1547525-0004-G-0005.mxd

3.6.1.2.6 Waste Placement Procedures

Waste placement is planned on a year-round basis, subject to acceptable weather conditions. Waste placement may cease during periods of inclement weather such as high winds, major precipitation events, extreme cold periods, or inability to compact waste due to frozen conditions. A decision by CNL to curtail waste placement operations may be based on considerations for safety of workers and the public, the potential for release of contaminants, and the ability to meet engineering requirements for waste placement or compaction.

A Slope Stability Analysis was completed to provide the specifications used to determine the maximum slope for the placement of each waste stream, as applicable. This analysis was complete to confirm that the design cover and slopes can accommodate placement of the various waste throughout the ECM waste profile without adverse effects to the liner systems and long-term cover performance. Settlement of the waste is anticipated to occur primarily due to consolidation of the waste/cover soil and waste degradation. The waste placement procedures outlined in below have been developed to maximize in-place density and to reduce void space, thereby reducing the potential for future differential settlement of waste.

Initial Select Waste Lift

As each cell is constructed, the initial waste is placed as a 1 m-thick select waste layer that will consist of homogeneous Type 1 soil and soil-like waste. The select material is free of large stones/boulders or other foreign materials, and relatively free draining (e.g., free of silts and clays). The purpose of the select material layer is to protect the leachate collection system and underlying composite base/sidewall liner components during subsequent waste placement. Equipment used to place the select waste layer will work from the perimeter of the cell, toward the center, and only on top of previously placed waste. To prevent possible damage to the collection layer or other components of the composite base/sidewall liner, no equipment is permitted to operate directly on the surface of the leachate collection system layer.

Only low-ground-pressure equipment is used for construction, operations, and maintenance until the initial 1 m select waste lift is in place. Placement of debris, large bulky items, or packaged waste is not permitted within approximately 10 m of the sidewall slopes or within 1 m of the leachate collection and final cover systems.

Subsequent Waste Lifts

Waste placement into each cell will proceed initially by unloading waste at the cell perimeter and grading it into position directly with bulldozers or similar heavy equipment. Waste is placed in operational lifts of 3 m thickness against the berm sidewalls of the cell. Each operational lift is placed in approximately 0.3 m layers. The initial operational lift is developed to a width of approximately 20 m from the sidewall of the cell and a minimum of 50 m in length. A second operational lift may be started on top of this lift. Waste placement continues in this manner until approximately five operational lifts are placed, including the final 1 m select waste layer immediately under the final cap. The configuration of the ECM will allow almost parallel and symmetrical operational lifts to be developed, since the design of the final cap parallels the floor in the major area of the landfill.

Each individual layer of waste is spread in an approximate thickness of 0.3 m, or as otherwise specified below for specific waste types. Each loose layer is compacted and documented before additional layers are placed on top. Actual fill sequence and placement procedures may vary based on the volume and type of incoming waste at any given time during the NSDF operational phase. As operations proceed, multiple ECM access roads and waste transfer areas are developed to support the multiple work faces of the operational lifts. Waste handling or placement restrictions may be required due to the presence of contaminants in the waste material.

One of the main objectives of waste placement is to reduce void space to limit the potential for the future differential settlement of the waste. As a result, the waste is placed in controlled lift thicknesses and compacted. Waste materials of high compressibility will not be placed in concentrated areas, but are spread in thin lifts over larger areas. Materials with no compressibility (such as demolition debris) will also be placed to avoid concentrated areas. Each lift of waste is graded at approximately 2% to provide surface runoff from the waste within the disposal cell. Surface water runoff and non-contact water is managed in accordance with the Surface Water Management Plan (Section 3.7).

Placement of Debris Waste

Placement of debris waste may require longer time periods to complete an individual waste layer for compaction and final disposition within the cell (i.e., final compaction of soil or soil-like waste around the debris waste). In addition, debris waste to be grouted in place may be collected in a final placement location until it is cost-effective and space-efficient to grout the debris in place. Another option for placing debris in the ECM is to construct a trench out of waste soil or wood/steel forms for placement of debris. Once the trench or form is full of debris, it may be grouted to satisfy compaction requirements. Placement of debris, large bulky items, and packaged waste is not permitted within 10 m of the sidewall slopes or within 1 m of the leachate collection system and final cover system.

Dust Control during Waste Placement

Dust control is conducted to support waste placement operations in accordance with the Dust Management Plan during loading, transportation, placement and compaction operations. Work areas that have the potential for generating dust will require dust suppression techniques and monitoring. The primary dust control method will include water spraying or misting techniques (e.g., water trucks). Water application is controlled to avoid generation of free liquids. Fixatives (e.g., chemical suppressant) may also be used for dust control during winter season or shutdown periods, and for use as daily/interim cover. The use of fixatives is reviewed prior to application for potential effects on leachate and surface water runoff generated by the ECM.

Air quality is monitored for dust that may contain radiological and hazardous constituents to support worker and environmental protection as described in the Environmental Protection Plan (Section 3.13.2.2). Waste placement activities may be restricted or suspended if unacceptable amounts of dust are generated due to winds or other site conditions. All excavating, loading, hauling, and dumping operations are suspended when wind speeds exceed the specified criterion.

Waste Placement Mapping Plan

A Waste Placement Mapping Plan will be developed to facilitate accurate recording and documentation of cell and ECM development, as well as the placement locations of the different waste types in the cells. The plan will specify a coordinate system and methods for dividing the ECM into an appropriate grid spacing for each operational lift of waste placed. The information will be recorded on an as-placed map/plan. As waste is placed in the ECM, the locations/elevations are documented on the placed waste map/plan and updated on a regular basis during operations.

3.6.1.2.7 Waste Placement by Waste Type

The waste materials planned for disposal in the ECM have unique characteristics for unloading, placement, and compaction. Specific waste placement requirements pertaining to the six different waste types (as defined in Section 3.2.1.1) are presented in the following subsections.

Type 1 Waste - Soil and Soil-Like Waste

Type 1 waste comprises approximately 37% of the total waste volume. Due to its soil-like characteristics, Type 1 waste is readily placed, graded, and compacted using standard construction methods and equipment. Grading is completed using dedicated bulldozers or similar heavy equipment, and compaction will be performed using a dedicated wheel tractor soil compactor or sheepsfoot roller. This material may also be used as berm material for berm containment areas used to contain Type 3, 4, and 5 wastes.

Type 1 waste is placed and graded in approximate 0.3 m lifts and compacted to a minimum of 92% Standard Proctor Density (SPD). The minimum 92% SPD compaction reduces settlement and is readily achievable over a wide range of soil conditions. Compaction procedures are developed and adjusted as required in the field based on waste characteristics, moisture levels, and the type and size of compaction equipment used.

The moisture content of the Type 1 waste is controlled within 1% below and 3% above optimum moisture content to attain the required level of compaction through the addition of water. Waste with high moisture content may be spread and allowed to dry before compaction. Alternatively, waste that is too moist for compaction may be amended with drying agents such as hydrated lime to allow compaction.

Type 2 - Comingled Debris with Soil or Soil-like Waste

Type 2, comingled radioactive waste, refuse and soil or soil-like waste, comprises approximately 8% of the total volume of waste and is placed and graded in lifts up to 0.3 m in thickness using a bulldozer or equivalent. Compaction of the waste is performed using a combination of a landfill compactor or a wheel tractor soil compactor, depending on the percentage of refuse within the waste. The components of the variable Type 2 waste is uniformly distributed throughout the disposal cell lift during placement to the extent practical. Placement is conducted to reduce concentrated areas of refuse and to limit the potential for differential settlement.

Organic debris consists of paper, cardboard, wood, and other biodegradable materials. This waste is uniformly distributed throughout the disposal cell to the extent practical. Type 1 waste may be placed above layers of organic debris and compacted with conventional compaction equipment to reduce void space and limit settlement.

Type 3 - Non-soil-like Waste

The volume of Type 3, non-soil like waste, requiring disposal in the ECM is estimated to be less than 1% of the total waste volume and highly variable in nature. Waste placement and compaction procedures are developed on a case-specific basis for Type 3 waste. Type 3 waste consists of bulk material placed in specific dedicated and prepared containment areas within each disposal cell. The dedicated areas are typically constructed on top of Type 1 waste, with perimeter berms constructed of Type 1 material. The waste is spread evenly within the bermed containment area to a maximum thickness of approximately 0.3 m.

The size of the designated bermed Type 3 waste containment areas are based on the volume and delivery schedule of the waste. The perimeter berms are approximately 1 m in height with 1H:1V side slopes, resulting in a 2 m base width. The Type 3 waste is typically covered with approximately 0.3 m of Type 1 or Type 4 waste.

Type 4 - Decommissioning and Demolition Waste

Type 4, decommissioning and demolition waste, constitutes the majority by volume of waste (approximately 39%) to be disposed of in the ECM, including both bulk materials (e.g., crushed concrete, masonry, asphalt), as well as individual pieces of debris (e.g., structural steel, process piping, process equipment, and other building materials).

Type 4 waste will generally not be compressible and, as such, will require special placement and backfilling procedures to reduce void space associated with this waste.

Type 4 waste is typically placed in lifts having a maximum thickness of 0.3 m in designated and prepared areas that are co-located with placement of Type 1 waste. Typically, each lift of Type 4 bulk waste is covered with approximately 0.3 m of Type 1 waste before subsequent lifts of Type 4 bulk waste are placed. Where practical, Type 4 bulk waste may also be used to cover Type 3 waste within its designated bermed containment areas before covering with Type 1 material.

Non-bulk Type 4 waste (i.e., individual pieces of debris) is placed individually in designated and prepared areas on top of Type 1 waste and backfilled with Type 1 material. The base of the designated and prepared areas will typically consist of a minimum of 0.3 m of Type 1 waste. Each individual piece (or bundle) of Type 4 waste is backfilled with Type 1 waste to reduce void space around the material.

Steel and concrete beams, concrete monoliths, and building debris are placed with appropriate spacing between the beams to allow a proper compaction of Type 1 waste around the debris. Large concrete and building debris will be broken down into pieces with placed dimensions no greater than 0.3 m prior to acceptance for disposal in the ECM. Void space between monoliths must be less than 10%. Type 1 waste is placed around the monoliths in approximate 0.3 m lifts and compacted using conventional compaction equipment. If the void space is greater than 10% then grout may be placed between the monoliths to reduce void space. Concrete, steel, and building debris are placed in flat individual pieces within the ECM and will not be stacked.

Small building rubble is placed with a minimum horizontal spacing between rubble loads. Individual small rubble loads are spread as necessary for proper filling of voids with Type 1 waste. Type 1 waste is placed around the small rubble in approximate 0.3-m lifts and compacted using conventional compaction equipment.

Type 5 – Packaged Waste

Type 5, packaged waste, includes containers and drums and comprises approximately 15% of the total waste volume and are placed in specific dedicated and prepared containment areas within each disposal cell. The dedicated areas are constructed on top of previously placed Type 1 waste, with perimeter berms constructed of Type 1 material or alternatively, forms of plywood or steel.

Wastes having activity greater than 400 Bq/g for alpha–emitting radionuclides and 10,000 Bq/g for long lived beta radionuclides will require special packaging and/or treatment to ensure the radioactive wastes remain isolated and contained in the waste packages. The expected life span for these packages will be confirmed during final design.

The size and configuration of each designated containment area is based on the volume and delivery schedule of the Type 5 waste, but would generally be limited to a maximum size of 30 m by 60 m. The perimeter berms are typically a minimum of 1.2 m in height with 1H:1V side slopes. The placement area and perimeter berm height will accommodate standard 320-L overpack drums, box containers, and other waste containers. The base of the dedicated area is constructed with an approximate 0.3 m-thick layer of granular drainage media, graded at 2% toward a contact water catchment area. The granular base layer may also be overlain by a geogrid to provide enhanced subgrade bearing capacity and to function as a working surface for the placement of the packaged waste.

Steel or metal box containers and concrete caissons or canisters are placed into the dedicated area on an individual basis using standard construction equipment such as loaders or excavators, and if required, specialized equipment such as cranes. These containers may be stacked two high and may be placed adjacent to one another in an arranged pattern, with grout or other flowable fill material placed to reduce void space below 10%. Alternatively, containers may be placed with spacing such that conventional compaction equipment can compact between the containers. Type 1 waste is placed around the containers in approximate 0.3 m lifts and compacted using conventional compaction equipment. Concrete caissons/canisters may be positioned above previously placed caissons/ canisters with a layer of Type 1 waste in between but will not be stacked. Box containers and concrete caisson/canisters will not be placed within 1 m of the leachate collection system.

Drummed waste is placed into the dedicated area on an individual basis using a hydraulic excavator equipped with a hydraulic grapple or other drum-handling equipment. Two layers of drums are placed in each operational lift, with the layers separated vertically by a 0.15 m-thick grout layer. Drums are placed in an upright position on the prepared base, evenly spaced with no separation between adjacent drums. Rows of adjacent drums are positioned in a staggered pattern to minimize the overall footprint of the dedicated area and to minimize the void space between drums. The void space between drums will be grouted or flowable fill may be used to meet compaction requirements. Drums placed in the ECM will have a maximum of 10% void space within the container to prevent drum collapse.

Other smaller packaged waste in rigid metal containers is handled and placed in a similar manner to the drummed waste, using standard construction equipment such as loaders or excavators, and if required, specialized equipment such as cranes. Wooden containers are crushed and their contents evenly spread and compacted similar to Type 2 waste. Packaged waste in compressible containers, such as bagged waste (e.g., used PPE&C, insulation) is handled and placed similar to Type 2 waste.

Asbestos-containing materials are to be received in packaged form and handled and placed within the ECM using debris trenches in accordance with the Ontario *Environmental Protection Act, Regulation 347, General – Waste Management*. The location of the packaged asbestos-containing material is documented in accordance with the as-placed waste placement mapping plan.

The Bearing Capacity and Settlement Analysis was completed to confirm the minimum separation distance and related placement criteria for each operational lift of Type 5 waste. The analysis addresses the placement of multiple types of drums, containers, boxes, and concrete caissons or canister configurations including waste layer assumptions and related placement criteria.

Type 6 - Miscellaneous Waste

Type 6, miscellaneous waste, is any waste that does not fall within the definition of Type 1 through 5 wastes. The volume of Type 6 waste is anticipated to be less than 1% of the total volume, and as such, handling and placement procedures are developed based on the individual characteristics of the waste as its need for disposal arises. The handling and placement procedures are developed to ensure safe and secure placement of the waste, in a manner that does not affect the integrity and long-term performance of the ECM.

3.6.1.3 Disposal Cell Cover

Cover materials are used to provide shielding and to reduce personnel radiation exposure or contact with contaminated materials. These cover materials include operational soil cover, fixatives, plastic tarping, or similar materials to provide separation from the waste material. The operational cover (daily or interim cover) will consist

of clean soil stockpiled on site as it becomes available from the excavation of the NSDF base or other suitable borrow sources or grout for some Type 4 and Type 5 waste. In addition to waste cover or shielding, the time spent on the working face is limited and the working distance from the waste is maximized to the extent practical to maintain worker exposures ALARA. These approaches to reduce worker exposure are discussed in greater detail in Section 3.13.2.1.

3.6.1.3.1 Daily Cover

At the end of each working day, the surface of the active waste areas is temporarily covered with a soil layer (approximately 0.15 m-thick), tarpaulin, fixative or crusting agent, or similar temporary cover system primarily to control the release of fugitive dust from the surface of the waste. Daily cover also fulfills a number of other functions such as reducing erosion of placed waste, reducing blowing litter, reducing odour, discouraging vector and vermin activity, improving equipment access to the active disposal area, and maintaining a more aesthetically pleasing site appearance. Alternatively, grout may be used as daily cover in areas that are using grout for void reduction. When possible, a coarser grained soil is used as daily cover to promote hydraulic connection between waste lifts and allow leachate to more readily infiltrate to the base of the ECM.

3.6.1.3.2 Interim Cover

During ECM development, areas which are not considered part of the active disposal area, but are scheduled to receive additional waste at some future time, are temporarily covered with soil, tarpaulin, fixative or crusting agent, or similar temporary cover system to promote non-contact surface water runoff and to limit exposure of waste. Interim cover consists of a 0.3 m layer of clean soil (if soil is used as the cover material). Interim cover soil will be a relatively tight-grained soil to promote runoff and reduce infiltration into the waste material. Interim cover is placed on disposal areas that will remain inactive for more than 30 days, after which time waste placement will resume.

Interim cover is removed prior to the resumption of landfilling, to the extent practical, to promote hydraulic connection between waste lifts. Removal of the interim cover will allow leachate to more readily infiltrate to the base of the ECM, thereby limiting perched leachate conditions. In areas of the cell where top-of-waste final contours have been achieved, interim cover is temporarily placed until a sufficient area has been reached to warrant commencement of construction of the final cell cover system.

3.6.2 Wastewater Treatment Plant

3.6.2.1 Operating Strategy

A general description of the operating strategy for the WWTP process is provided in this section.

3.6.2.1.1 Influent Equalization

During normal operation, it is expected that the operator will use a single equalization tank to contain daily wastewater input flows. If flows are low, the operator may elect to accumulate wastewater in the equalization tank for a period of time without operating the treatment system. When sufficient wastewater has accumulated, the operator can start the treatment system and process the accumulated wastewater from the equalization tank. This cycle would then be repeated.

During high flows of contact stormwater, the wastewater characteristics may be more dilute. The operator may choose to divert high flows to a different equalization tank for storage, sampling, and characterization. If the accumulated dilute wastewater meets all requirements for discharge, it may be discharged directly from the equalization tank via installed piping connections to the final effluent tank(s). If certain COPC exceed discharge

requirements, the operator will process the wastewater through the WWTP processes as necessary to meet discharge requirements.

3.6.2.1.2 Chemical Precipitation

When sufficient wastewater has accumulated in the equalization tank, the operator will collect a sample and perform laboratory jar tests to determine chemical dosages needed to achieve effective precipitation. The operator will then initiate the automatic treatment process, and will visually observe the chemical precipitate formed in the chemical precipitation tanks to confirm that the chemical dosages and mixing rates are resulting in adequate performance. The chemical precipitation process will be shut down when all wastewater has been processed from the equalization tanks. Mixers will continue to be operated during periods when wastewater is not processed, to keep precipitated solids in suspension and prevent settling in the chemical precipitation tanks. If the treatment system is expected to be idle for an extended period of time, the contents of the chemical precipitation tanks can be transferred using temporary equipment to the membrane filter feed tank for processing through the membrane filtration system, or to the residuals storage and conditioning tanks for dewatering.

3.6.2.1.3 Membrane Filtration

During periods when the chemical precipitation process is in operation, the membrane filtration system will be operated to remove precipitated solids from the pretreated wastewater. The operator will monitor the pressure drop across the membranes and permeate rate to evaluate the hydraulic performance of the filtration system, and determine when the system should be taken out of service for cleaning. The operator will also monitor the concentration of solids in the process tank and will adjust the rate at which concentrated residuals are pumped to the residuals conditioning and storage tanks. Depending on the time required for cleaning and the volume of chemically-precipitated wastewater in the membrane filter feed tank, the chemical precipitation process may continue operation or may be shut down during the membrane cleaning cycle. After cleaning, the membrane filtration system will be returned to operation.

3.6.2.1.4 Permeate pH Adjustment

The permeate pH can be adjusted to a range of setpoint levels depending on the specific ion exchange resins used for the polishing treatment process. The permeate pH adjustment system will be activated when the chemical precipitation and membrane filtration processes are in operation. The operator will select the pH for optimum performance of the downstream polishing process, and the system will automatically reduce the elevated pH of the membrane permeate to the selected pH setpoint. The downstream ion exchange resins selected based on the ongoing pilot scale test are effective over a broad pH range, but it is expected that the pH of the permeate will be controlled at a neutral pH of approximately 7.

3.6.2.1.5 Granular Activated Carbon

Effluent from the permeate pH adjustment process will be directed through the GAC vessels when the wastewater contains organic constituents at concentrations that exceed discharge requirements. During periods when organic constituent concentrations meet discharge requirements, the GAC process can be bypassed. During operation, the operator will periodically collect samples of the effluent from each GAC vessel for analysis of target organic COPC. When organic COPC are detected in the effluent from the first GAC vessel, it will be removed from service, and the lag vessel will be placed in the lead position. Spent GAC will be removed from the vessel and replaced with fresh GAC, or the entire vessel will be replaced with a new vessel containing fresh GAC. The vessel containing

fresh GAC will be placed in the lag position. Pressure gauges will be provided on the inlet and outlet of each vessel for monitoring of pressure drop across each vessel.

3.6.2.1.6 Ion Exchange

The ion exchange process will be operated when the effluent from chemical precipitation and membrane filtration contains heavy metals and/or radionuclides at concentrations that exceed the discharge requirements. The process will bypassed when discharge requirements can be met without polishing by ion exchange.

During operation, the operator will periodically collect samples of the effluent from each ion exchange resin vessel for analysis of target COPC. When target COPC are detected in the effluent from the lead ion exchange resin vessel, the resin will be removed from the vessel and replaced, or the entire vessel will be replaced with a new vessel containing fresh resin. The lag vessel will then be placed in the lead position, and the vessel containing fresh resin will be placed in the lag position. Pressure gauges will be provided on the inlet and outlet of each vessel for monitoring of pressure drop across each vessel.

3.6.2.1.7 Final pH Adjustment

The effluent pH will be adjusted to meet the effluent discharge pH requirement of 6 to 9 standard units. The effluent pH adjustment system will be activated when wastewater is being treated through one or more processes, and requires adjustment of pH prior to discharge. The operator will select the discharge pH, and the system will automatically control the effluent pH to the selected pH setpoint. The effluent pH adjustment system can be idled during periods when wastewater is not being processed.

3.6.2.1.8 Final Effluent Storage

The final effluent storage tanks will contain final effluent during periods when the WWTP is operated to process wastewater from the equalization tanks. The operator will periodically collect samples from the effluent tanks for analysis of COPC to confirm that the effluent complies with all discharge requirements. Effluent will be discharged by gravity from the final effluent storage tanks to surface water (wetlands). Due to the presence of low concentrations of cations and anions (such as chloride) in the final effluent that are not removed by chemical precipitation and polishing treatment, recycle and reuse is not recommended to avoid concentration of these ions in the WWTP and effluent.

3.6.2.1.9 Residuals Storage and Dewatering

The filter press will be operated when sufficient residuals have accumulated in the storage and conditioning tanks to ensure a full filter press load can be processed. The press will be filled with residuals from the storage and conditioning tanks, and the pressure will be gradually increased. Filtrate will exit the filter press recessed chambers through the filter cloths that line the chambers. When the press cycle is completed, residuals that remain in the feed chamber will be discharged back into the residuals storage tank, and the press chambers will be opened to allow dewatered filter cake to be discharged to the storage container located beneath the filter press.

3.6.2.1.10 Chemical Storage and Metering

The operator will track the inventory of chemicals, and will arrange for chemical deliveries when needed to maintain adequate inventory for treatment. The operator will also prepare powdered activated carbon slurry and diatomaceous earth slurry for use when required for treatment.

3.6.2.2 Treated Effluent Discharge Concentrations

Removal efficiencies were calculated for COPC present in the wastewater simulant used for the pilot scale test. The removal efficiencies calculated for each process are summarized in Table 3.6.2-1.

Table 3.6.2-1: Removal Efficiencies for Non-Radionuclide Constituent Concentrations in Wastewater

Constituent	Concentration in Wastewater (mg/L)	Average Pilot Test Wastewater Concentration (mg/L)	Chemical Precipitation and Membrane Filtration		Zeolite Resin		Strong Acid Cation Resin	
			mg/L	% Removal	mg/L	% Removal	mg/L	% Removal
Aluminum	0.15	0.532	0.019	96.5	—	—	0.02	0
Arsenic	0.004	0.0052	<0.001	80.6	—	—	—	—
Barium	1.8	1.84	0.055	97.0	—	—	<0.02	63.6
Cadmium	0.003	0.00325	0.000296	90.0	—	—	0.000286	3.4
Calcium	100	374	34.5	90.8	—	—	4.8	86.0
Cesium	0.01	1.008	0.96	4.4	0.00258	99.7	—	—
Chromium	0.005	0.0537	<0.0005	99.1	—	—	—	—
Cobalt	—	0.00428	0.00102	76.3	—	—	00.001	1.5
Copper	0.1	0.125	<0.0025	98.0	—	—	—	—
Iron	125	122	<0.06	100.0	—	—	—	—
Lead	0.02	0.02	<0.001	95.0	—	—	—	—
Magnesium	68	44.6	23	48.4	—	—	28.8	0
Manganese	5.8	6.18	0.062	99.0	—	—	0.048	22.6
Nickel	—	0.0305	0.0073	76.2	—	—	0.0073	0
Phosphorous	1.3	1.38	<0.6	56.6	—	—	—	—
Potassium	26	27.6	26.8	2.8	—	—	28.4	0
Silicon	5	5.13	0.37	92.8	—	—	0.35	5.4
Sodium	100	1,160	—	—	—	—	—	—
Strontium	0.1	1.87	0.442	76.3	—	—	0.003	99.2
Uranium	—	0.0011	<0.0002	81.8	—	—	—	—
Zinc	0.2	0.209	0.014	93.2	—	—	0.017	0

mg/L = milligrams per litre; % = percent

3.7 Management of Surface Water

Surface water is categorized as contact or non-contact runoff. Contact runoff is developed during site operations and is considered contaminated and must be treated by the WWTP. It is generated in the area within the ECM and, more specifically, within the active cells of the containment berm. Non-contact runoff is developed at the NSDF site, both within and outside of the ECM. Runoff generated by areas external to the ECM includes undisturbed lands, roadways, buildings, parking lots, and laydown/stockpile areas.

The management of surface water runoff from the ECM has both a contact and non-contact component:

- design of the contact component uses runoff volumes to address WWTP requirements and uses back to back 100 year storm events as design criteria; and,
- the non-contact component uses peak flows from the 100 year event to address runoff from the ECM cover and runoff volumes from the 100 year event to address storage and pumping requirements within the ECM for those areas that are not covered.

Overall, the design of the surface water management system for the NSDF site is to achieve the following objectives:

- to mitigate erosion and intercept sediment during construction from transport off-site during wet weather events;
- to control the quantity of surface water discharge from the NSDF site to pre-development peak flow rates; and,
- to provide quality treatment of surface water from the NSDF to meet the requirements of the Ontario Ministry of the Environment and Climate Change (MOECC), settling suspended sediment and ultimately protecting receiving watercourses/waterbodies.

The surface water management system consists of four main elements:

- collection (i.e., site grading, inlets, catchbasins);
- conveyance (i.e., ditches, sewers, culverts);
- treatment (i.e., settling/detention ponds); and,
- outlet to receiving waters (i.e., East Swamp wetland).

During the construction phase, erosion and sediment control measures will be in place to mitigate the effects of sediment transport. The measures will include the use of erosion control blankets, as needed, to control erosion on steep slopes, check dams in ditches and swales, and the three proposed surface water management ponds that will be constructed to serve as interim sediment control facilities during construction, and then as stormwater management facilities during the operations, expansion and post-closure periods. Both the ECM and external areas, including the WWTP, parking lots, administrative and maintenance buildings, and laydown areas will be subject to erosion and sediment control measures during construction.

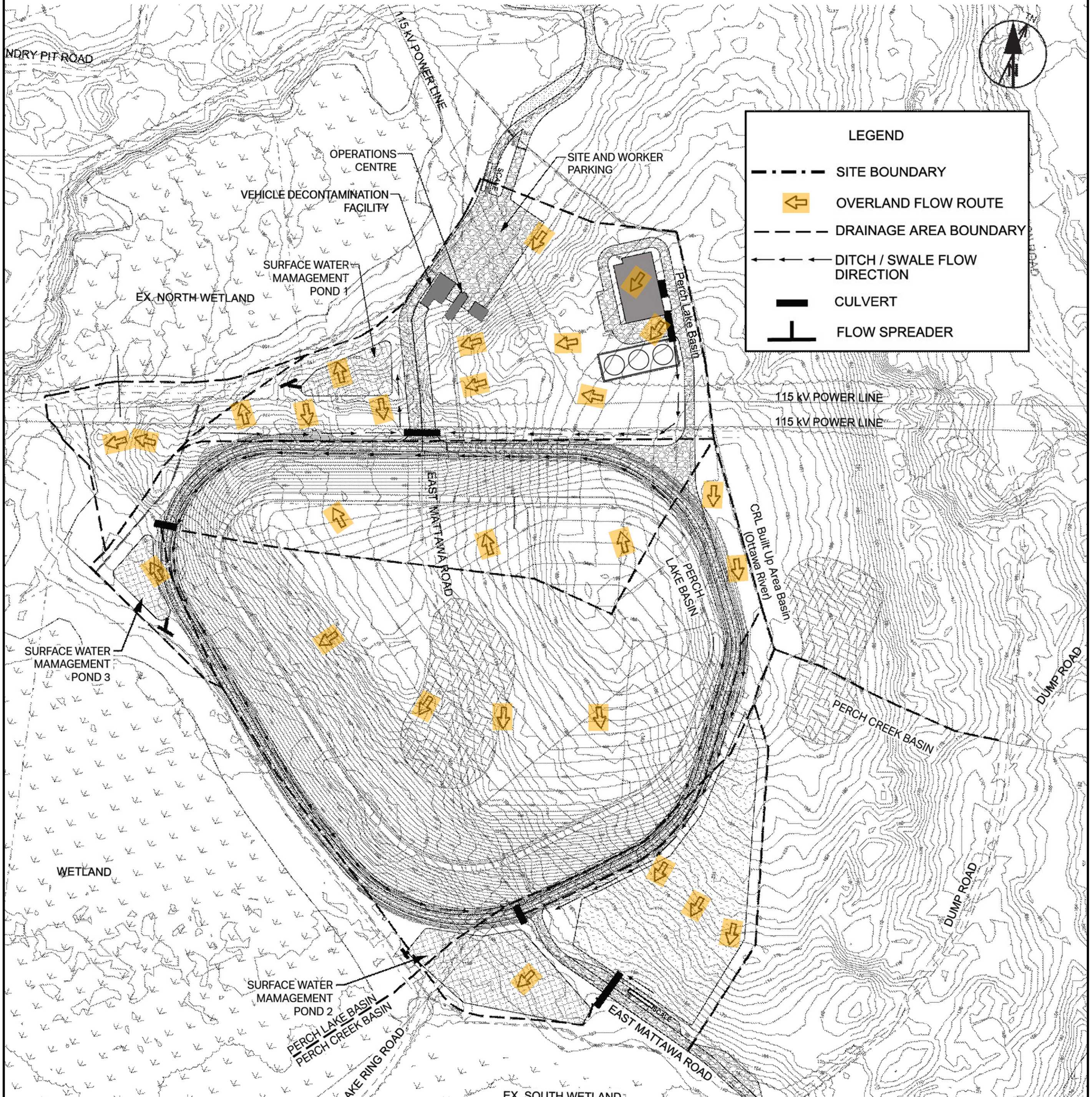
Site operations include surface water management for the ECM and all external areas. Surface water from all external areas will be conveyed by ditches, swales and culverts to surface water management ponds that will

address water quality and water quantity criteria established for the wetland receiving waters and, ultimately, Perch Creek. Contact surface water drainage from the active cells of the ECM will be to the WWTP. Non-contact surface water drainage from completed cells and yet-to-be-activated cells will be directed either by gravity to the external surface water management system or to temporary holding ponds within the ECM and then pumped to the external system and the three surface water management ponds. There will be a need to address pre-treatment of surface water run-off from the active cells prior to conveyance to the WWTP and a need to establish conveyance mechanisms (gravity and pumping) from the interior of the ECM to the surface water management ponds.

3.7.1 Surface Water Management Ponds

The surface water management ponds are designed to address erosion and sediment control concerns during construction by providing interim sediment control and by providing water quality/quantity controls during operations, closure, and post-closure. The three surface water management ponds are located to address the proposed layout and drainage patterns (Figure 3.7.1-1).

- Surface water management pond 1 is at the north end and will receive run-off from proposed buildings and parking lots. The outlet will be via channel and dispersion outlet (spreader), to the wetland to the north (East Swamp).
- Surface water management pond 2 is to the south and receives run-off from the post-closure ECM and adjacent laydown/stockpile area. The outlet will be via channel and dispersion outlet (spreader), to the the wetland to the southwest (Perch Lake Wetland Complex).
- Surface water management pond 3 is to the west and will receive run-off from the post-closure ECM. The outlet will be via channel and dispersion outlet (spreader), to the wetland to the northwest (Perch Lake Wetland Complex).



REFERENCE(S)
1. FIGURE OBTAINED FROM B1550-505240-PLA-001 DELIVERABLE 14.2, REVISION B

CLIENT
CANADIAN NUCLEAR LABORATORIES

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT

TITLE
SURFACE WATER MANAGEMENT PLAN

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	MM
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0004	0.0	3.7.1-1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm

S:\Clients\Canadian_Nuclear_Laboratories\NSDF\99_PROJ\1547525_NSDF_EIS\40_PROD\0004_EIS_Section_3\1547525-0004-G-0007.mxd

The current surface water management pond footprints reflect the overall storage required to control post-closure flows to predevelopment levels for the 2-year through to 100-year rainfall events at the site. This volume also contains the storage required for sediment control during construction and water quality control during operations. The current footprints typically assume a maximum 100-year operating water level at a 3 m depth with 1 m of freeboard that includes allowance for climate change impacts and rain on snowmelt.

The target surface water quality objective is provided by MOECC in their *Stormwater Management Planning and Design Manual* (MOECC 2003), which reports a 60% total suspended solids (TSS) removal that provides a basic water quality treatment for discharge to the receiving wetland. The choice of basic treatment over normal or enhanced levels of treatment (70% and 80% TSS removal, respectively) was influenced by the receiver being a contaminated wetland and not a watercourse. The wetland also has a sediment trapping function that will provide additional treatment to ultimately enhance level of treatment for Perch Lake and Perch Creek (the ultimate receiving waters).

Roadway, sidewalk and parking lot winter maintenance activities that may release road salt to the environment, include snow plowing/shoveling and de-icing practices, salt and sand storage and snow stockpiling, removal and disposal. The current winter maintenance practices outlined in the CRL Salt Management Plan provide for effective management of salt use. The application of road salt on the NSDF site is to be limited as salt residual within contact water and/or leachate may compromise the treatment effectiveness of the WWTP systems. Instead, alternative products such as a sand-stone mixture are being considered.

For the surface water management ponds, the outlet configuration includes orifice controls for quality and quantity. As well, the outlet spillway transitions to a concrete slab flow spreader (broad-crested weir) for eventual discharge to the receiving wetlands. It is configured as a leveled concrete slab parallel to the downstream wetland with both a parallel upstream swale to contribute to an even flow distribution and a downstream gravel transition strip to provide additional erosion mitigation.

For each surface water management pond, the water level will be sampled continuously from May through November inclusive to estimate the inflow and outflow of each pond. The outlet water quality will be sampled twice annually as a composite grab sample during a minimum 1 hour rainfall of greater than 30 millimetres (mm) to determine if there is any contact surface water or leachate contamination of the non-contact surface water; TSS will also be measured. Appropriate procedures to identify emergency spill occurrences and response, as well as appropriate response to non-contact surface water or leachate contamination will also be implemented as described in the Operations and Maintenance Plan and Contingency Plan.

Facility inspections will be completed twice annually to confirm that inlets and outlets are clear of debris and to confirm that there are no major erosion issues at the inlet or outlet. As well, the integrity of berms and outlet structures will be confirmed by visual inspections that would identify any animal burrowing activity or active soil erosion. Inspections will also include an annual sediment level monitoring component to identify sediment clean-out requirements. Sediments will be extracted by excavation equipment and will be disposed of based on sediment sampling, testing, and classification according to MOECC standards or stockpiled, de-watered and re-used on-site for ECM cover operations. The sediment removal assessment follows procedures identified in the Stormwater Management Planning and Design Manual (MOECC 2003).

3.7.2 Drainage Ditches and Swales

All roadways, including the perimeter road, have ditches that convey not only roadway drainage, but drainage from adjacent lands, to the surface water management ponds. These have been designed to convey the 25-year post-development peak design flow. Annual maintenance activities will identify any erosion problems. In addition, a maintenance review will be completed after major storm events and after the annual spring melt to confirm there are no major erosion issues.

3.7.3 Culverts and Sewers

Where drainage crosses roadways, culverts are sized to convey the 25-year design event without road overtopping. A box stormsewer has been sized to convey the 100 year flow to surface water management pond 1, adjacent to the access road due to constraints imposed by property and roadway limits that preclude the use of a ditch. Annual maintenance activities will identify any erosion or blockage problems. In addition, a maintenance review will be completed after major storm events and after the annual spring melt to confirm there are no major erosion or blockage issues at the culvert and sewer inlet or outlet.

3.7.4 Flow Paths

Major system (i.e., 100-year) flow routes follow the road system and ditches to the relevant surface water management ponds. The probable maximum precipitation (PMP) flow generally follows the major system route using the roadway, related ditches and adjacent lands. The PMP flow will exceed the surface water management ponds attenuation capacity, but is adequately conveyed by inlet and emergency outlet structures adjacent to the surface water management ponds.

3.7.5 Outlets

The major flow system for all three surface water management ponds will outlet to an adjacent wetland and will be dispersed by level spreaders that will provide an even flow distribution to the wetland with an appropriately wide dispersal pattern. Current surface water management ponds outlet locations are limited by the site boundary (greater than 5 m separation required) so that there is no discharge from the spreader directly to the wetland. Local topography between the level spreader and the wetland, as well as any setbacks, has influenced the location of the level spreader on site. Annual maintenance activities will identify any erosion problems. In addition, a maintenance review will be completed after major storm events and after the annual spring melt to confirm there are no major erosion issues at the dispersion outlets.

3.8 Management of Waste Generated by the Project

All wastes that arise as a result of the construction, operations, and closure phases will be safely managed and in accordance with CNL's Waste Management Program. The CNL Waste Management Program prescribes that management of solid waste at CNL-operated sites is completed in a safe and environmentally responsible manner that meets or exceeds applicable regulations and standards, and limits current and future environmental effects and liabilities. Facilities and activities within these sites are planned, developed and operated or conducted in a manner that reduces both the volume and the level of hazard of all wastes that are generated during the entire life cycle of the facility or activity. Under the Waste Management Program, wastes are managed in accordance with CNL's Management of Solid Waste and Management of Liquid Waste documents, and CNL's Waste Generation and Handling Standards.

Canadian Nuclear Laboratories' Management of Solid Waste and Management of Liquid Waste documents define the key requirements and processes to confirm that:

- non-radioactive, radioactive, hazardous, biomedical, and mixed solid and liquid wastes generated at CNL operated sites, or received by CNL operated sites from external organizations are managed in a safe and environmentally responsible manner and in accordance with CNL's Environment Policy and Waste Management Program;
- the quantities and level of hazard of solid and liquid wastes are reduced; and,
- proper classification of the differing waste types.

Solid wastes are also managed in accordance with CNL's Waste Generation and Handling Standards, which prescribes that wastes are segregated and handled separately based on compatibility and intended means of processing, storage, and/or disposal. In general:

- clean and likely clean wastes are segregated as to the intended method of recycle, reuse or disposal;
- hazardous wastes are segregated based on their physical, chemical and biological hazard characteristics; and,
- radioactive wastes, including other wastes that meet the WAC, are segregated based on the acceptance criteria as set out by the Waste Receiver, and may include segregation by physical, chemical, and radiological content, as well as packaging and labelling criteria.

The Waste Management Plan developed for the NSDF Project provides the plan for managing the waste generated during the construction, operations, and decommissioning of the NSDF in accordance with CRL waste management requirements. Conventional (non-radiological) waste generated during construction and operations will comprise consumables and sanitary waste. Conventional waste generated from the NSDF Project during construction and operations may be managed at CRL's Inactive Landfill, located to the east of the NSDF Project site (Figure 1.0-1). Types of consumables include non-reusable/recyclable construction materials, and other regular waste generated at an industrial work site. Each contractor on-site will be responsible for their own housekeeping and waste handling/disposal. Standard mitigation measures will be implemented for storage of

conventional waste at the site, prior to disposal at the landfill (e.g., collection and storage in appropriate wildlife-resistant containers). Construction materials will be re-used or recycled, if possible.

Hazardous (non-radiological) materials generated during construction and operations will be typical of those generated for construction of large industrial facilities and will include solvents, chemicals, cleaners, aerosol cans, compressed gases, oils and lubricants. These materials will be managed, including storage, use and disposal, in compliance with applicable legislation, codes and CNL's Waste Generation and Handling Standards. Once collected by a licensed hazardous waste disposal company, these wastes will be transferred off-site to licensed waste management facilities for treatment and/or disposal.

No radioactive waste is expected to be generated during site preparation and construction activities. In the event any material is found to be contaminated with radioactive material, it will be separated and managed according to existing procedures established for all CNL operated sites, which are consistent with applicable regulations. The primary radioactive waste generated during operations of the NSDF (aside from the leachate generation and residual solids) includes personal protective equipment and clothing, consumable materials, and miscellaneous wastes. These wastes will be managed according to CNL's Waste Generation and Handling Standards for radioactive waste.

3.9 Management of Emissions and Effluents

Emissions and effluents from the NSDF Project during the construction, operations, and closure phases will be managed according to CNL's Procedure for Management and Monitoring of Emissions. This procedure defines the key requirements, responsibilities, and processes for the management of radioactive and non-radioactive emissions at CNL operated sites. This document expands on regulatory requirements for the effective management of these emissions, and involves the following activities:

- identification and assessment of emission pathways;
- control and treatment of emissions;
- operational control monitoring; and,
- effluent verification monitoring.

Identification and assessment of emission pathways involves identifying routes by which radioactive and non-radioactive contaminants are likely to be emitted to the atmosphere, surface waters, ground or groundwater, or to off-site municipal sewer systems from CNL facilities during routine and non-routine events. The type and quantities of these contaminants to be emitted are characterized, and subsequently assessed for the likelihood of exceeding regulatory and internal emissions limits, the magnitude and likelihood of effects to the public, the potential for adverse effects to the environment, and the potential for public concern.

Control and treatment of emissions includes identifying mitigation to prevent, reduce, or limit release of emissions to the environment. To the extent practical, airborne and waterborne effluent containing contaminants are managed separately from non-contaminated effluent. Preventative maintenance programs are implemented to reduce the likelihood of system failures, and appropriate systems are in place to provide timely warning in the event of a failure or degradation of control and treatment systems. Operational control monitoring is completed to evaluate whether or not emission control and treatment systems are functioning as intended.

Effluent verification monitoring is intended to verify that emissions are below regulatory limits and includes measuring or estimating nuclear substances and hazardous substances being released in to the environment by a site or facility. An EVMP is established for the monitoring of radioactive and non-radioactive emissions. The overall EVMP for the CRL property is applicable to the NSDF Project; specifically, the Air Verification Monitoring Program and Liquid Verification Monitoring Program will be expanded to include the NSDF Project.

A passive landfill gas (LFG) venting system will be constructed contemporaneously with installation of the ECM final cover system. The LFG venting system is designed to mitigate buildup of excessive gas pressure under the low-permeability barrier components of the final cover that could, if it were to occur, result in damage/disruption of the cover system. LFG monitoring probes will also be installed around the perimeter of the ECM and will be monitored periodically during the ECM post-closure phase to detect evidence of potential LFG migration away from the ECM.

Monitoring of the treated effluent discharge will be completed in accordance with CNL's Management and Monitoring of Emissions Procedure. The Operational Control Monitoring Program (OCMP) for the CRL property will be expanded to include the NSDF Project, and will achieve the following objectives:

- to provide feedback to facility operators on system performance with respect to emissions to the environment within a time frame consistent with routine operational control decisions;
- to confirm the adequacy of controls on emissions from the source;
- to provide timely indication to facility operators of abnormal emissions that may be in excess of emission limits in order to initiate corrective action, incident reporting, quantitative monitoring, investigations or emergency actions as appropriate; and,
- to differentiate sources of abnormal emissions where there is more than one facility, system or subsystem that discharges to the environment through a single or common effluent stream.

A leachate monitoring program will be conducted at the ECM. The leachate monitoring program will be designed to characterize the leachate quality as the landfill is developed, and to ascertain unique indicator constituents that are diagnostic of the leachate. The leachate monitoring program including measurements of leachate depth in the LCS sump and leachate head in the LDS. Leachate collected by the leachate collection system will be pumped to the onsite WWTP for treatment. Leachate samples will be collected three times per year from the LCS and once annually from the LDS and be analyzed for constituents of concern.

Environmental monitoring is performed to assist in determining the effect of emissions in the environment surrounding a site or facility, and consists of measuring or estimating nuclear substances and hazardous substances present in the environment. Canadian Nuclear Laboratories maintains a comprehensive Environmental Monitoring Program for the CRL property to verify that radiation doses to members of the public as a result of radioactive releases from the site remain as low as reasonably achievable, social and economic factors being taken into account. The program demonstrates that releases from the CRL property do not exceed regulatory limits, and serves to verify that non-radioactive releases do not pose hazards to human health, and that neither radioactive nor non-radioactive pose hazards to the environment. Monitoring is completed through routine collection and analysis of environmental samples from numerous locations within the CRL property, as well as in

the surrounding communities. The Environmental Management Plan (EMP) for the CRL property will be expanded to include monitoring and sampling locations for the NSDF Project.

3.10 Closure Phase

3.10.1 End-state Objective

The Comprehensive Preliminary Decommissioning Plan (CPDP) is based on current information and describes the intended approach for decommissioning of all infrastructure, facilities, systems and components found on the CRL property. It provides information on the current site hazards, and is aimed to demonstrate that decommissioning can be completed, with existing technology, in a manner that provides for the protection and safety of workers, members of the general public, and the environment. The CPDP for decommissioning of the CRL property meets the requirements specified in the CNSC *Guidance Document G-219 Decommissioning Planning for Licensed Activities* (CNSC 2000) and is consistent with CSA Standard N294-09 *Decommissioning of Facilities Containing Nuclear Substances* (CSA Group 2009).

Final closure of the NSDF site is intended to achieve the following objectives.

- limit the need for future maintenance, for information on leachate, wastewater, surface water, groundwater, and landfill gas after closure;
- control, limit, or eliminate post-closure escape of radioactive and non-radioactive constituents, including leachate, contaminated run-off, or decomposition products to groundwater, surface water, and the atmosphere;
- result in an appropriate final cover slope over the ECM to mitigate the effects of settlement and achieve positive drainage off the ECM surface to limit infiltration, erosion, sediment transport and maintain cover stability; and
- be compatible with the anticipated end use(s) and the planned future ownership of the NSDF site and surrounding area and the overall CRL site.

Planning for decommissioning is an ongoing process, and planning assumptions are expected to change over time. Periodic revisions of the CPDP are completed as necessary to reflect changes in the proposed plan, including the decommissioning of facilities associated with the NSDF Project. An updated and revised Closure Plan will be prepared at the time of final closure based on actual, verified conditions through the end of the operational period of the NSDF Project. The final Closure Plan will be completed no later than the date that 90% of the total waste volume has been placed or 2 years prior to final closure, whichever comes first. The final closure plan will have information on updated remaining waste volumes, final contours and associated remaining site life including a detailed implementation schedule. Information that will be considered in the revised/updated closure plan will include the final inventory disposed in the facility, types of waste, locations of waste, and other relevant information.

Final closure of the NSDF Project will be completed in a manner consistent with the planned end-uses for the NSDF and surrounding areas, and the overall CRL property. CNL currently anticipates end-uses as one where most areas of the site will be classified for industrial use with some areas qualifying for unrestricted use. CNL anticipates this will be achieved in a phased approach, with: (1) the site reaching an interim state, during which post-closure activities will be performed, in year 2100; and (2) the of the post-closure care period occurring around year 2400. CNL anticipates that during this 300-year period, institutional controls (ICs) will be implemented and

long-term monitoring will be completed to demonstrate compliance with safety case assumptions. The ultimate end use(s) of the NSDF Project site will be determined by the Crown. The Crown is responsible for the long term management of AECL lands including the CRL property, the proposed location of the NSDF.

3.10.2 Operational Decommissioning

The design approach used for designing the NSDF Project is to incorporate waste placement and stabilization features into routine waste operations so that final closure activities are reduced, and those needing to be accomplished will be simplified and streamlined. This approach allows the major closure activities of cover placement and site stabilization to be completed during the 50-year operating period. As the time of final facility closure nears, only surface facility decommissioning and closure of the final phase of the disposal units will remain. The following design features are expected to contribute to simplifying final closure of the ECM.

- Voids inside drums are filled at the time of placement to the maximum extent practicable.
- Voids between drums are filled with non-compactable waste or non-compactable material (e.g., approved grout).
- Placement specifications and operating procedures for the disposal of all waste are designed to reduce settlement.
- Interim cover and final cover system placement progresses as disposal cells are filled. The early placement of the final cover system during the operating period ensures that anticipated settlement of the final cover system over these closed disposal unit cells occurs during the operational period. Installation of final cover in phases will help accelerate the timeframe for secondary settlement. The record of settlement for the closed cells is a measure of anticipated settlement performance for the then-open disposal cells that are closed during the closure period.
- Settlement magnitudes are expected to be minimal as a result of completing final closure construction in strict compliance with soil and geosynthetic material placement specifications and in accordance with inspection and testing procedures outlined in a stringent CQA Plan.

3.10.3 Decommissioning of Wastewater Treatment Plant, Infrastructure, and Support Facilities

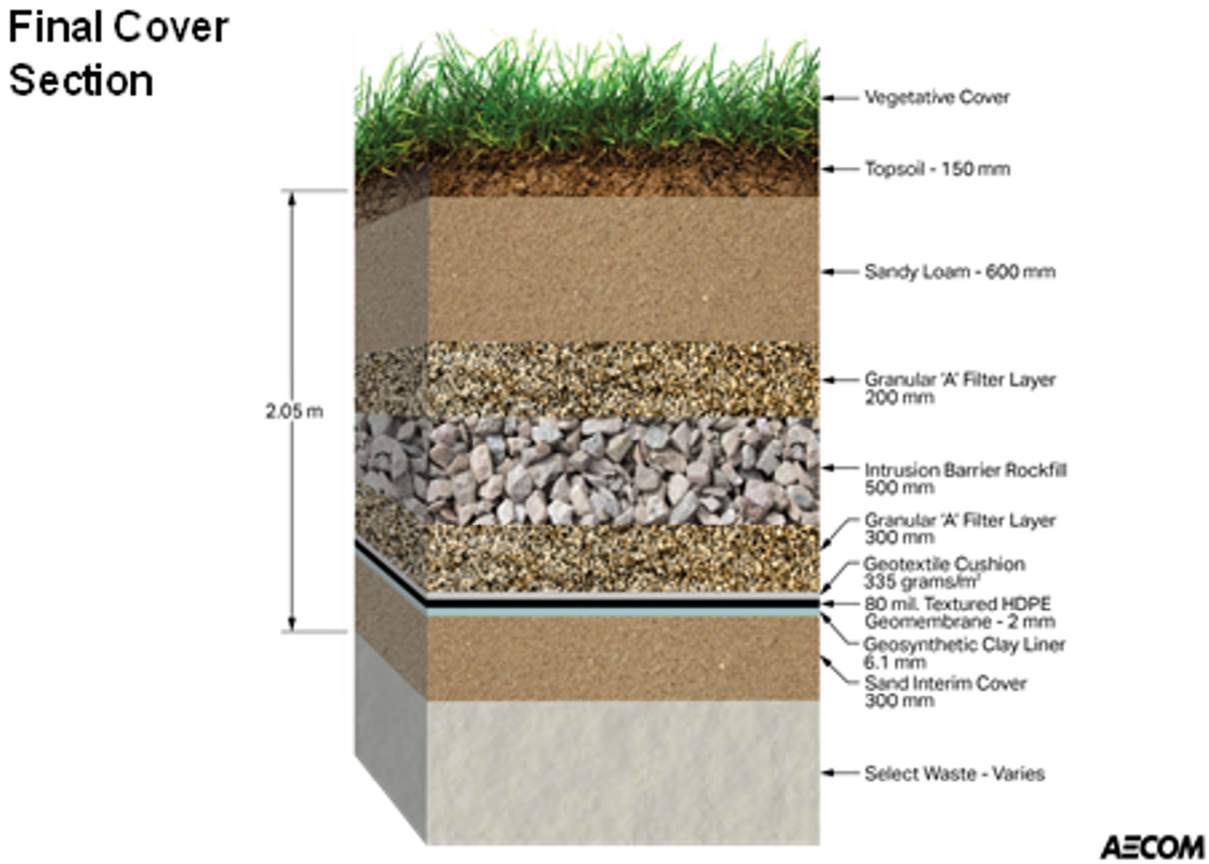
Decommissioning of infrastructure and support facilities will be completed by 2100. Buildings and services will be designated for decommissioning and demolition after NSDF Project site operations deems them of no further use. The general approach for decommissioning and demolition of buildings at the CRL property will be completed in a planned, orderly way to limit impact on shared services and adjacent buildings or services. Decommissioning will be prompt to the extent possible to limit care and maintenance costs. Structures will be decontaminated to the extent required to allow conventional demolition and enable waste materials to be reused or recycled. Release for recycling and reuse of materials will be completed to the extent practical. Concrete can be crushed for reuse as backfill at the decommissioning facilities. Metals and structural steel will be cleared for release to off-site recyclers. Upon post-closure of the NSDF Project ECM, it is anticipated that another similar or future disposal capability will be available to the CNL for radioactive waste.

Decommissioning of the WWTP and all associated structures will be performed after the leachate quantity no longer requires this facility for treatment and the leachate is able to be treated using a different technique or it

becomes more cost-effective to send leachate to an alternate off-site facility. Once the ECM is closed, the volume of water for treatment in the WWTP will reduce to a substantially smaller flow, as will the quantity of residual solids. Therefore, those solid wastes to be generated during the decommissioning of the WWTP will be packaged to meet the future storage or disposal capability. Waste associated with demolition of the WWTP and associated facilities will be dispositioned and disposed of off-site as determined at the time of decommissioning.

3.10.4 Final Cover Placement for the Engineered Containment Mound

A final cover system will be designed over the entire surface of the completed containment mound, to mitigate moisture infiltration into the waste and hence limit leachate generation. The final cover system will consist of a 2 m-thick engineered multi-layer system. A cross-section of the final cover system is shown on Figure 3.10.4-1 and the sequencing plan is shown on Figure 3.10.4-2. The final cover is designed to limit water infiltration, to direct infiltration and surface water runoff away from the ECM waste emplacement area, and to resist degradation by surface geologic processes and biotic activity (e.g., prevent burrowing of animals) and inadvertent intruder attempts to access or excavate into the wastes waste cell. A series of drainage control features will be installed in conjunction with placement of final cover over the ECM. A passive LFG venting system will also be installed in conjunction with the final cover construction as part of the final closure activities.



CLIENT
CANADIAN NUCLEAR LABORATORIES

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT

TITLE
CROSS-SECTION OF THE FINAL COVER

CONSULTANT
Golder Associates

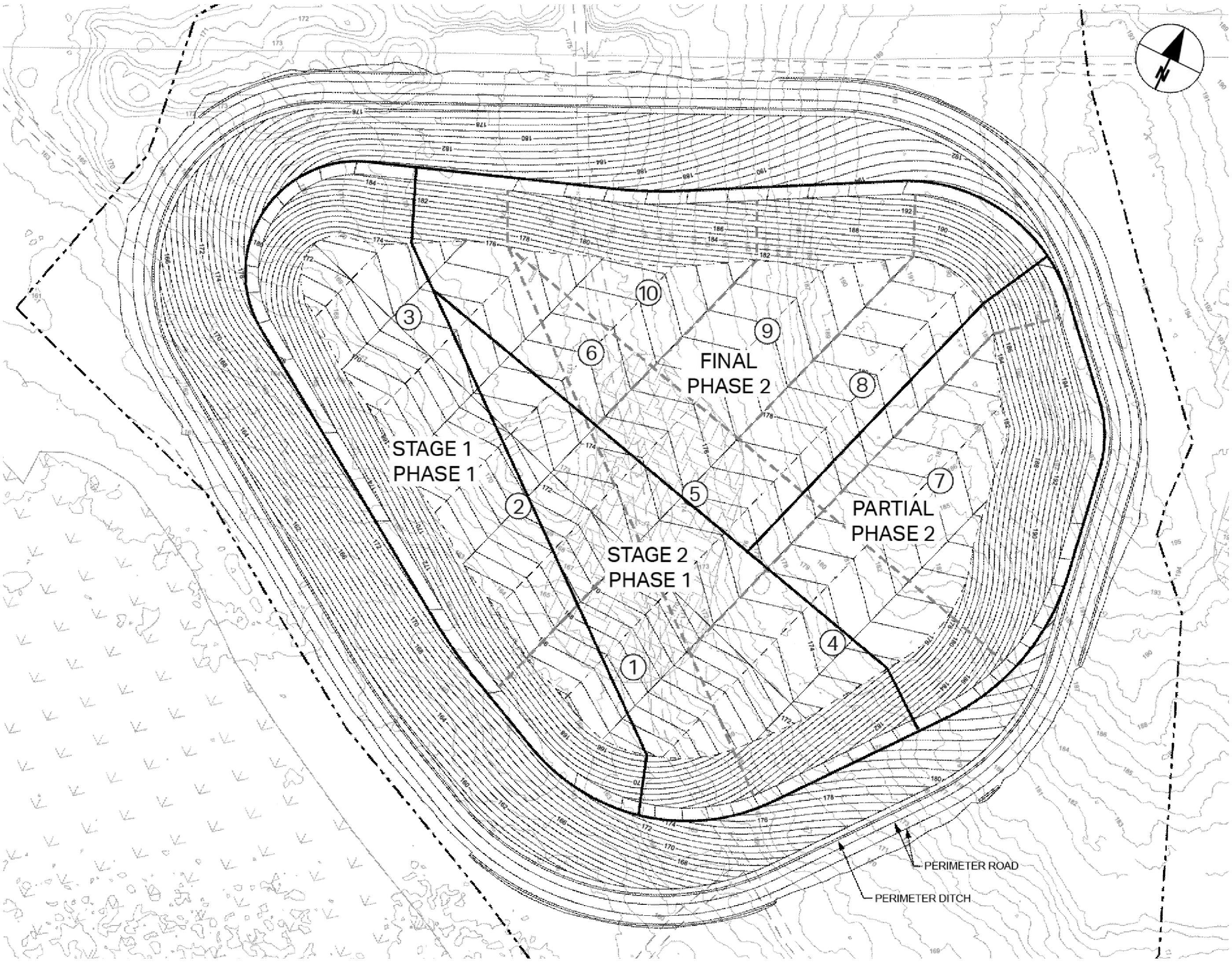
YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	MM
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0004	0.0	**3.10.4-1**

REFERENCE(S)
1. FIGURE OBTAINED FROM NSDF-508220-PLA-003 DELIVERABLE 14.5, REVISION B

S:\Clients\Canadian_Nuclear_Laboratories\NSDF\99_PROJ\1547525_NSDF_EIS\40_PROD\0004_EIS_Section_3\1547525-0004-G-0008.mxd

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm 0



REFERENCE(S)
1. FIGURE OBTAINED FROM B1550-505240-PLA-001 DELIVERABLE 14.2, REVISION B

CLIENT
CANADIAN NUCLEAR LABORATORIES

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT

TITLE
FINAL COVER SEQUENCING PLAN

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	MM
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0004	0.0	3.10.4-2

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm

S:\Clients\Canadian_Nuclear_Laboratories\NSDF\99_PROJ\1547525_NSDF_EIS\40_PROD\0004_EIS_Section_3\1547525-0004-G-0009.mxd

3.10.4.1 Component Layers in the Final Cover

3.10.4.1.1 Landfill Gas Venting Layer (Interim Cover) Layer

A described in Section 3.6.1.3, a 0.3 m minimum thickness interim sand cover layer will be installed directly above the waste material. This interim cover will provide for a smooth base surface for installation of the infiltration barrier component layers. Through maintaining a minimum cover of 0.3 m, the interim sand cover provides a firm subbase for the overlying geosynthetics and protects the infiltration barrier from damage by waste materials, such as exposed stones and demolition waste. It also provides a layer to promote lateral venting of landfill gas beneath the HDPE geomembrane/GCL barrier component in the final cover. Geovent strips (venting strip drains) will also be installed on top of the sand interim cover layer as part of the passive LFG venting system. The sand interim cover will be made smooth with a smooth drum roller (non-vibrating mode) as required to create a smooth competent surface for subsequent infiltration barrier placement.

3.10.4.1.2 Infiltration Barrier Component of Cover System

The low-permeability barrier portion of the infiltration performance cover system includes the composite HDPE geomembrane/GCL barrier portion of the final cover. A textured, HDPE geomembrane liner will be placed directly on the GCL. The geomembrane will serve as the upper (primary) barrier against infiltration through the cover into the buried wastes. It is also expected to prevent or limit the upward migration of radon and other landfill gases from the waste fill into the atmosphere.

The GCL functions as a lower (secondary) low permeability barrier that also limits the downward leakage through any potential defects that might exist in the overlying geomembrane liner. In addition, it provides a back-up hydraulic barrier in the unexpected event that the geomembrane experiences deterioration over the design life of the facility. This role of the GCL requires that its hydraulic conductivity remain at a low value over the design life of the ECM. In the event of a hole or leak in the HDPE geomembrane, the clay portion of the GCL would hydrate, forming another barrier to mitigate any potential leakage flow downward into the waste profile, thereby creating essentially a self-healing effect on the hole or leak in the HDPE liner.

The composite infiltration barrier subsystem of the cover is designed to be installed 1.75 m below the surface of the cover system (the estimated maximum frost penetration depth in the cover). The GCL will provide an additional means of restricting infiltration and is less susceptible to significant damage from freeze-thaw or potential long-term differential settlement than a compacted clay layer.

3.10.4.1.3 Granular, Cushion and Intrusion Barrier Components of Cover System

A cushion geotextile and a 0.3 m-thick Granular A filter layer will be installed above the HDPE geomembrane. The geotextile is designed to protect the HDPE geomembrane from potential puncture damage by particles in the Granular A filter layer. A 0.5 m-thick intrusion barrier rockfill layer will then be placed over the Granular A filter layer (see Section 3.10.3.1.4).

The 0.3 m-thick granular protection layer will provide, in conjunction with the underlying HDPE geomembrane, a means for conveying lateral drainage within the cover of water that percolates through the upper layers of the final cover. Granular A rock is generally composed of high-stability graded sand and gravel.

The principal function of the 0.2 m-thick Granular A filter layers above the intrusion biobarrier layer is to provide a natural filter layer to limit the possibility of fines migrating downward from the sandy loam fill layer to the underlying

intrusion biobarrier to help reduce the potential for future clogging of the biobarrier layer. It also allows for some degree of lateral flow diversion within the cover system.

3.10.4.1.4 Intrusion Barrier Rockfill Layer

The 0.5 m thick intrusion barrier rockfill layer is included to deter burrowing animals and roots from potential deeper-rooted plant species reaching and possibly damaging the cover lining system, as well as penetrating into and transporting contaminants from the waste fill. This rockfill layer would also help deter inadvertent future intrusion into the buried wastes by humans. The layer will also provide for some lateral drainage of water that percolates through the upper layers of the cover.

The intrusion barrier rockfill layer will be constructed of approximately 200 mm minus rockfill material. This rock material will be produced from rock fragments removed from the ECM footprint area in order to achieve the design subgrade surface and/or be obtained from an appropriate rock borrow source. Rock material derived from on-site excavation will be crushed as required to meet rock sizing requirements. The rock will consist predominantly of gravel (5 mm to 75 mm sizes) and cobbles (75 mm to 200 mm sizes). The percentage of fines (i.e., silt and clay sizes) for this type of material will be specified to be less than 10%. Limitation of the fines content to less than 10% is important for maintaining a rock-to-rock skeleton structure with strong interlocking, rapid drainage, and low-moisture retention characteristics.

The effectiveness of the rockfill intrusion barrier against root penetration relates to its inability to hold the moisture and nutrients that plants need to survive. The roots would therefore remain within the overlying topsoil layer (0.15 m thick) and sandy loam fill layer (0.6 m thick). The effectiveness against burrowing animals relates to the large particle sizes (i.e., up to 200 mm) and the strong interlocking between the crushed rock particles. The types of burrowing animals anticipated to be present at the CNL site and NSDF site (e.g., rodents, ground hogs, fox, squirrels and bears) are unlikely to expend the additional energy required to dig into the hard intrusion barrier containing these larger rock sizes beneath the 0.95 m thick overlying soil/granular layers.

3.10.4.1.5 Vegetative Cover/Erosion Protection Component of Cover System

A two-layered soil component will be installed over the upper (0.2 m-thick) Granular A filter layer as the final cover component. This soil cover system contains a loosely compacted 0.6 m sandy loam layer overlain by a 0.15 m-thick vegetated topsoil layer. The proposed cover soil layer and topsoil layer thickness' are consistent with that required by the Ontario Ministry of Environment Landfill Standards (O. Reg. 232/98). The 0.15 m-thick topsoil layer will be placed and loosely compacted over the sandy loam layer. This layer is terminated at the berm road with a 0.3 m-thick rockfill layer at a 2:1 slope. This rockfill provides stability to the termination area of the vegetative cover component of the final cap. It also provides erosion protection against any surface water sheet flow that does not enter into the designed riprap downdrain.

The primary purpose of the 0.6 m-thick sandy loam layer is to provide moisture retention for plant uptake and evapotranspiration. This moisture retention is important for promoting surface plant root development, which is important for transpiration and minimizing surface erosion processes. This layer also provides additional gamma radiation shielding and additional confining stress for the final cover lining system. The soil type will meet the U.S. Department of Agriculture (USDA) soil gradation requirements for either loam, sandy loam and/or sandy clay loam. A minimum organic matter content is not necessary. For optimizing establishment of vegetation, the soil will also exhibit Atterberg Limits within specified limits. The maximum particle size will be 100 mm to facilitate spreading

and compaction. The cover soil can be placed/compacted in three-200 mm thick lifts, with compaction provided by a tracked dozer rather than a heavy drum compactor.

The material comprising the topsoil must meet the USDA soil gradation requirements for either loam, sandy loam and/or sandy clay loam, with a minimum organic matter content of 4% (dry weight basis) and a pH in the range of 6 to 8. The organic matter component can be either natural or introduced by mixing in composted material. The topsoil layer will be augmented with nutrients to promote growth of a healthy stand of hardy grasses. The maximum particle size will be limited to 50 mm to facilitate spreading, seeding and root development. Normally, the topsoil layer is spread as a single lift with nominal compaction from a tracked dozer.

The final cover will be vegetated to provide an aesthetically pleasing surface, enhance evapo-transpiration and reduce the potential for erosion. The vegetation will be limited to grass species that are maintenance free and drought resistant. Mowing of the grass is not necessary. Trees will not be allowed to establish on the final cover as they may cause considerable damage to the topsoil and soil cover layers, as well as expose the intrusion barrier if uprooted due to heavy winds.

Vegetation will be established and maintained by watering, fertilizing, weeding, mowing, trimming, dethatching, core aerating, replanting, and performing other operations as required to establish healthy, viable grassy vegetation. Bare or eroded areas will be rolled, regraded, replanted, and remulched in the same way as in the original installation to produce a uniformly smooth grassed surface. Treatments will be applied as required to keep grass and soil free of pests and pathogens or disease.

3.10.4.1.6 Final Cover Resistance to Long-Term Erosion

A soil loss/erosion calculation was completed for the proposed ECM final cover system. The Revised Universal Soil Loss Equation for Application in Canada method was used in the calculation. The results show that the average soil loss for the final ECM cover system is estimated at 0.21 tonnes per hectare per year and 1.12 tonnes per hectare per year, for the vegetated top slope, and vegetated upper side slope portions of the final cover system. Both of these calculated soil loss amounts are lower than the maximum annual allowable soil loss of 5.0 tons per acre per year.

3.10.4.2 Final Grading and Drainage Plan

The final cover system will be constructed at slopes between 5% (20 horizontal (H):1 vertical (V); overall slope for the top slope portion of the cover) and 25% (4H:1V) for the side slope portion of the cover. This top slope also has a herringbone pattern similar to the floor, with cross slope between the ridge and valley of 2%. This allows for the shedding of surface water to mitigate infiltration into the mound, minimizing leachate generation. This design also allows for minor differential settlement to occur while maintaining positive surface water drainage. From the top slope area, the mound side slopes are at a maximum 4H:1V (25%) slope. This allows for the shedding of surface water, minimizes erosion and sediment transport, and optimizes the volume that can be contained within the mound, while meeting stability requirements.

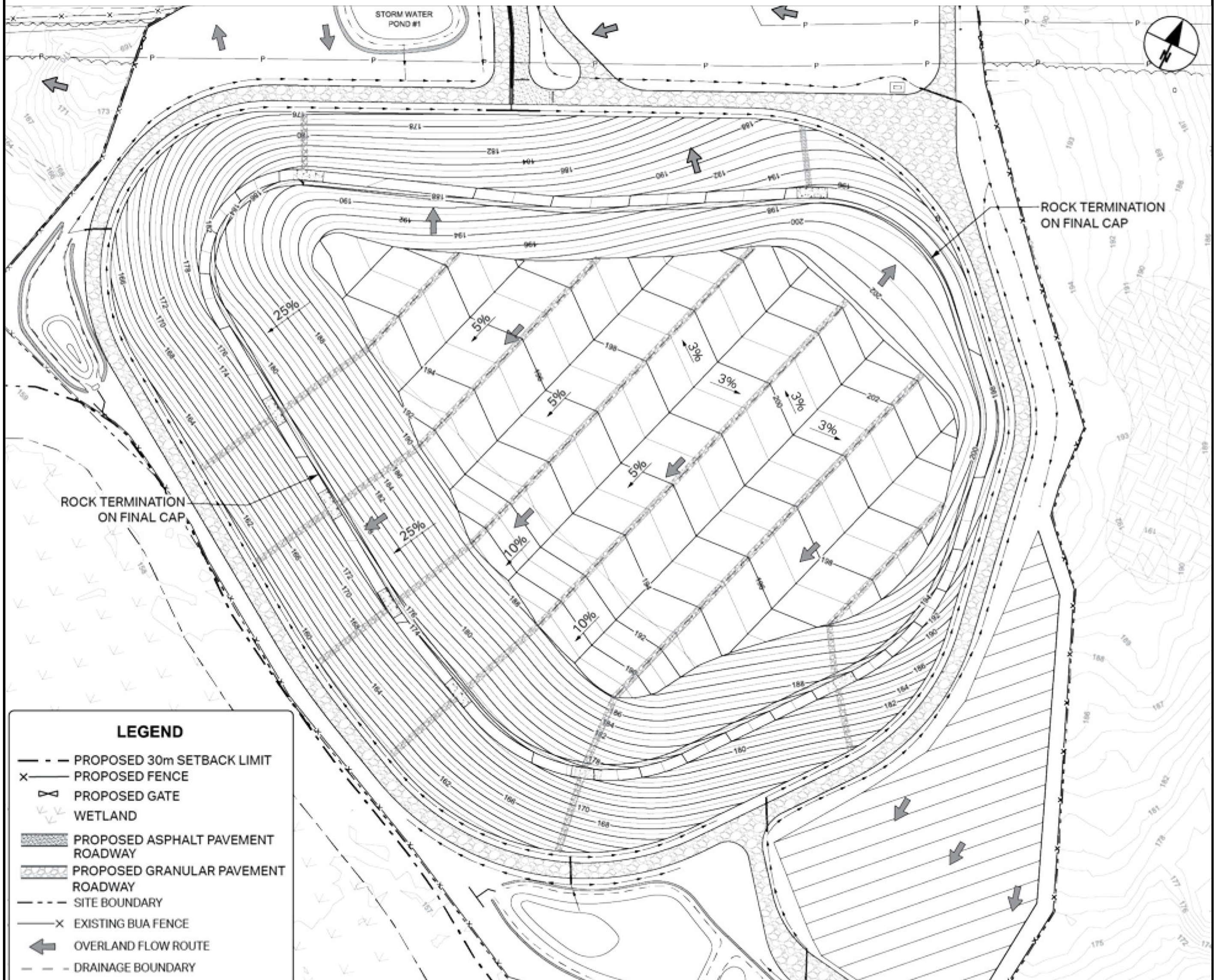
In order to manage the stormwater runoff from the ECM cover system, the cover system design incorporates a series of shallow, trapezoidal, riprap-lined drainage channels (2.5 m-wide at widest point, 12 inches in depth) installed in the surface along each “ridge” in the “ridge and valley” style 5% top slope portion of the final cover system. Filter fabric will be installed beneath the rip-rap material in each channel. These channels will be directed toward riprap-lined down drains that will be constructed to pass under the ECM perimeter berm access road. These down drains will convey the runoff water toward the ECM perimeter road drainage ditch. The channels are

designed to convey water at low velocity. Where slopes require, channels would include additional rock material to dissipate energy and prevent erosion or transport of materials.

The down drains are designed to dissipate the energy without being eroded. The down drains would consist of rock-lined chutes, underlain by a geotextile layer, and would serve to prevent erosion of the underlying cover and waste materials. Each downdrain will be equipped with stilling basins at the benches and at the connections to the perimeter ditch. The rock-lined stilling basins are designed to create a hydraulic jump to dissipate energy from the water.

The perimeter road ditch will route the runoff it receives from each downdrain structure via gravity around the ECM perimeter where it will then flow into discharge culverts to one of three stormwater ponds located outside the ECM perimeter road. These run-off controls are designed to minimize ponding of water into the closed ECM, erosion of the cover and underlying waste materials, destabilization of the ECM structure, and damage to access roads. Without controls, run-off could eventually lead to the creation of gullies and ravines that could compromise the integrity of the final cover system and/or the ECM structure.

The ECM final grading and drainage plan also includes collection ditches along the top of the ECM berm road to collect side slope drainage. The run-off from the collection ditches will be routed to the downdrains and ultimately to the perimeter ditch and a stormwater detention pond. Figure 3.10.4-3 provides the final grading and drainage plan for the ECM final cover system.



REFERENCE(S)
1. FIGURE OBTAINED FROM NSDF-508220-PLA-003 DELIVERABLE 14.5, REVISION B

CLIENT
CANADIAN NUCLEAR LABORATORIES

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT

TITLE
FINAL GRADING AND DRAINAGE PLAN

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	MM
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0004	0.0	3.10.4-3

3.11 Post-Closure Phase

The post closure is expected to last for 300 years and to start around 85 years from today. The 300-year post-closure life of the NSDF provides a means of ensuring the continued safe and effective function of the disposal facility following facility closure. Less frequent maintenance and care are required as the post-closure life progresses. A Post-Closure Care Plan will be developed and will be a living document that must be modified as needed to adapt to field conditions, programs, instrumentations, technology updates, and contingencies. Reporting requirements are subject to change based on changing conditions. Changes will primarily be made based on the extent that monitoring data confirms that the site and facilities are performing as projected and as required.

The NSDF must be maintained during the 300-year post-closure phase in order to meet the following performance requirements:

- prevent unacceptable dispersal of radioactive materials through environmental pathways;
- detect early the release of radioactivity;
- confirm the leachate collection system maintains structural integrity throughout 500 years;
- confirm the final cover system can withstand damage from degradation over the design life;
- confirm the vegetated topsoil of final cover system does not exceed an erosion rate of 5 ton/acre/year and does not have gully initiations under the anticipated runoff tractive stress;
- maintain the final cover at an appropriate slope to mitigate the effects of settlement and achieve positive drainage off the ECM surface to minimize infiltration, erosion, sediment transport and maintain cover stability;
- confirm that safety is provided by passive means during the post-closure service;
- execute applicable environmental requirements with regard to monitoring and surface water management systems/drainage features; and,
- evaluate the power systems throughout closure for potential upgrades to maintain post-closure performance requirements.

Once closed, the ECM (together with related closed NSDF facilities including the WWTP), will require regular monitoring and maintenance to ensure its integrity and performance. During the first year immediately following final closure, post-closure inspection and maintenance activities are expected to be most frequent. Early detection of any concerns or deficiencies is critical to a successful post-closure program. Inspection and maintenance activities are designed to identify problems before they develop into a need for corrective action. More frequent inspection events to achieve the program requirements as determined by CNL may be required. If deficiencies are found, an appropriate course of action must be determined and executed with expediency to mitigate potential undesired effects.

Maintenance activities for the ECM are primarily associated with limiting erosion from surface water run-on/ run-off and ground settlement within the ECM.

The finished surface of the ECM is elevated from the surrounding terrain, which limits the quantity of surface water entering the ECM from areas outside the extent of the ECM. The topographical slopes within the ECM footprint

are sufficient to promote drainage, and by lining the ECM surface water collection ditches and stilling basins with rip rap and other erosion control measures, sediment transport and erosion will be minimized. Construction, operation, and closure activities of the ECM are designed to provide a stabilized waste array with the purpose of minimizing settlement, and water infiltration. Also, because the disposal cells are closed and covered in stages, CNL will have the opportunity to observe the performance of the portions of cover system placed over time.

Construction, operation, and closure activities of the ECM are designed to provide a stabilized waste array with the purpose of limiting settlement, and water infiltration. However, subsidence or slope instability may indicate differential settlement occurring beneath the surface. The cover will be inspected for depressions, cracking, or other deformities in the cap shape for evidence of differential settlement.

Trees will not be allowed to establish on the final cover because their root systems can cause damage to the cover layers if, for example, the tree falls over due to wind; roots can disrupt low-permeability layers resulting in an increase in their hydraulic conductivity. Maintenance activities include removal of trees and other deep-rooted type vegetation, as well as conducting physical inspections for animal burrows over the ECM surface. In order to mitigate erosion and protect the ECM cover, the turf must be considered satisfactory. Satisfactory turf is considered a healthy, uniform, close stand of grass that is free of noxious weeds and surface irregularities, with coverage exceeding 90%. Maintenance activities will use the access roads that are constructed around the perimeter of the landfill and top of berm.

Performance monitoring will be completed to confirm that the ECM is functioning as intended. This monitoring will be completed in accordance with the operational control monitoring and EVMP outlined in CNL's Procedure for Management and Monitoring of Emissions (see Section 3.9). The post-operational monitoring program is intended to:

- demonstrate compliance with site-closure requirements;
- provide data to support long-term impact evaluation, such as long-term impacts on groundwater; and,
- provide records for facility closure and for regulatory review.

As the post-closure period progresses, it is expected that much of the environmental sampling can likely be terminated or reduced except for groundwater monitoring, which must be carried on to provide data to support long-term effects evaluation. After facility closure, the primary pathway for unintended radionuclide releases from the completed phases of the ECM to the environment would be through the groundwater. The groundwater monitoring program for the operational phase will be continued during the initial period after facility closure but will gradually be reduced if no radionuclide or chemical constituent migrations are identified.

Groundwater wells will be monitored at the frequency required throughout the post-closure period. The monitoring program includes water elevation measurements to determine groundwater flow directions and gradients, and sampling to monitor groundwater quality. A groundwater monitoring network will be developed including installation of groundwater monitoring wells to monitor hydraulic and chemical conditions in preferential flow zones in both vertical and horizontal orientations along the critical flow pathways.

The main emphasis of the groundwater monitoring program is to monitor locations that are downgradient from the ECM-lined disposal area footprint. Monitoring wells screened within the overburden/shallow bedrock interface zone are expected to lie within the primary groundwater flow path; these monitoring wells will comprise the primary

monitoring program for the ECM facility. The groundwater monitoring program developed for the NSDF project will be consistent with the existing CNL site groundwater monitoring program with respect to well construction and installation requirements, sampling frequency, and required analytical parameters. Initial sampling frequency will likely be twice per year (Spring and Fall) consistent with the existing site groundwater monitoring program.

Institutional controls are anticipated to be required when transitioning from the end of the "interim state" to the post-closure care period. Institutional controls are mechanisms designed to appropriately limit access to or uses of land and facilities, to protect cultural and natural resources, to maintain the physical security of facilities, and to prevent or limit inadvertent human and environmental exposure to residual contaminants. Institutional controls include administrative and legal controls, and may also include certain physical controls (e.g., fences and gates).

Institutional controls are important in helping to protect engineered barrier systems by providing a means to ensure that the barriers remain effective, are not showing signs of failure, or are continue to limit the potential for being vandalized or damaged by outside elements (natural or human) in any way. The NSDF is designed to promote safety through passive means during post-closure. Security and surveillance will be provided by CNL staff. The NSDF site security features will include signage, fencing, gate, and cameras. A chain-link fence will deter intruders and animals from site access. A controlled gate on the north side of the property may be unlocked to allow personnel access for required maintenance and observation. Cameras will be strategically placed by CNL to capture visual surveillance on the site. Features will be maintained and cared for with the intended use per manufacturer's specifications. All nighttime security lighting and other required security equipment will be provided by CNL as needed.

Institutional controls also include methods to preserve knowledge and to inform current and future generations of potential hazards and risks. Such administrative or legal controls help to minimize the potential for human exposure to contamination or protect the integrity of a remedy. Institutional controls work by limiting land or resource use by providing information to modify or guide human behavior at the site. Institutional controls will be prepared at the time of final closure of the ECM and related NSDF facilities and will be updated as necessary during, and at the end of the interim period to address changes in jurisdiction of authority and changes in other requirements that may occur as they relate to ultimate final closure and post-closure care of the NSDF facilities.

3.12 Human Resource Requirements

The construction, operation, closure and post-closure phases of the NSDF Project will require administrative and supervisor staff, engineering and environmental monitoring personnel, and construction workers. Table 3.12-1 summarizes the expected averaged labour requirements during construction, operations, closure and post-closure, including contractors. The construction is planned over two years and has a variable labour force depending on the number of parallel activities being performed. The averaged labour force over the duration of the construction phase is in the order of 45 full time equivalents (FTEs), with peak manpower expected to be close to 60 FTEs (Table 3.12-1).

Limited maintenance and inspection will occur in off-shift hours. Operations occur over a 50 year period, with an average labour force of 45 FTEs (although this will be adjusted based on operational demand). Closure and Post-closure labour force requirements will be substantially less than requirements for the operations phase.

Table 3.12-1: Summary of Labour Force Requirements for the Near Surface Disposal Facility Project

Project Phase	Labour Force	Types of Positions
Construction	Between 30 and 60 FTE over a 2 year period	Administrative and Supervisor Staff Construction Management Engineering/Technical Support Staff Equipment Operators Skilled Trades General Labour Environmental Monitor
Operations	45 FTE	Administrative and Supervisor Staff Mechanical/Technician Engineering/Technical Support Staff Equipment Operators Environmental Monitor Truck Drivers (transport of waste)

FTE = Full Time Equivalents.

3.13 CNL's Safety Policies, Objectives, and Programs

3.13.1 CNL's Safety Policies and Objectives

Canadian Nuclear Laboratories has established several corporate policies relevant to employee, public and environmental safety. The following policies will be followed for all NSDF Project activities:

- quality assurance;
- employee health and safety;
- environment;
- Nuclear Material and Safeguards Management Program; and,
- security.

The safety objectives that follow from the above policies maintain that:

a) Radiation exposures to facility staff, on-site personnel, and the off-site public resulting from the normal facility operation, Anticipated Operational Occurrences and credible accidents are:
   - below the regulatory limits (Canada Gazette 2000);
   - As Low As Reasonably Achievable (ALARA); and,
   - as per CNL's Radiation Protection Requirements.

b) Radioactive releases and radiation exposures to the facility staff, on-site personnel, and the most exposed group of the off-site public resulting from abnormal events will be addressed with the defence-in-depth philosophy. Doses will be:
   - first prevented;
   - mitigated; and,
   - accommodated through design, operating procedures, training, and administrative controls.

c) Releases of radiological substances to the environment will be first prevented, then mitigated, and then accommodated such that exposures are limited and are ALARA.

3.13.2 Existing Environmental, Safety and Security Programs

The following presents an overview of CNL's existing programs related to environment, safety and security. Canadian Nuclear Laboratories is responsible for and committed to providing to the health and safety of its employees and the public and the protection of the environment. These programs include, but are not limited to:

- Radiation Protection Program;
- Environmental Protection Program;
- Waste Management Program;
- Occupational Safety and Health Program;
- Emergency Preparedness Program;
- Nuclear Criticality Safety Program;
- Physical Security Program;
- Nuclear Materials and Safeguards Management Compliance Program; and,
- Fire Protection Program.

The above mentioned programs will be implemented during all phases of the NSDF Project. A brief description of each program is provided in the following sections.

3.13.2.1 Radiation Protection Program

Canadian Nuclear Laboratories' Radiation Protection Program is designed and implemented so that CNL complies with, or exceeds, the level of radiation safety that is required by the relevant regulations pursuant to the NSCA and CNL's Health and Safety Policy.

The fundamental objectives of the CNL Radiation Protection Program are to:

- limit the doses to less than the regulatory limits;
- limit doses to employees and members of the public to levels as low as reasonably achievable, social and economic factors being taken into account (ALARA principle); and,
- prevent detrimental non-stochastic (deterministic) health effects caused in employees and members of the public by CNL's use of radiation.

At all CRL facilities, these objectives are achieved through facility design, staff training, administrative exposure control procedures, contamination control requirements, and work planning and supervision. A combination of Action Levels and dose management tools are used to keep radiation doses to employees below regulatory limits and ALARA, social and economic factors being taken into account.

Canadian Nuclear Laboratories' ALARA program takes into consideration CNSC's regulatory guide to the ALARA principle (CNSC 2004) in the design of the NSDF Project. This program is used for the planning and control of radiological work, and includes guidelines and procedures for initiating, analyzing, planning, scheduling, executing and closing out radiological work so that radiation exposures and the risk of unplanned exposures are kept as low as reasonably achievable, economic and social factors taken into account. All new and non-routine activities (activities that will introduce any new or non-routine radiological aspects, hazards or safety concerns) require analysis by CNL's ALARA review process.

The ALARA principle for the NSDF Project design will be achieved by implementing zoning and access control measures, maintaining adequate shielding for structures and waste packages with high radiation fields, providing process equipment segregation, establishment of radiation alarms, continuous monitoring, and through operator training and approved procedures. Further reduction in operating staff doses is achieved by limiting releases through periodic inspection and preventive maintenance of equipment. This principle applies throughout the life cycle of the NSDF Project, from design to decommissioning.

3.13.2.2 Environmental Protection Program

Canadian Nuclear Laboratories' Environmental Protection Program provides compliance with applicable environmental regulatory requirements and requirements that CNL has adopted as a matter of policy. The program is registered under ISO 14001 and is designed to provide for the protection of the environment and the public in relation to CNL's activities. The Environmental Protection Program incorporates the following key elements of the ISO-14001 Environmental Management System (EMS) Standard:

Environmental Policy

- Commitment to pollution prevention.
- Setting environmental objectives and targets to support continual improvement of environmental performance.
- Complying with applicable laws, recognized standards and guidelines applicable to CNL activities.
- Reviewing the impacts of CNL facilities, projects, services and products on the environment.

Planning

- Identification and determination of significance of those environmental aspects associated with CNL's activities.
- Establishment of environmental objectives and targets.
- Development of appropriate plans and/or programs to achieve the objectives and targets.

Implementation and Operation

- Defining and documenting appropriate roles and responsibilities.
- Establishment and maintenance of operational controls over environmental aspects.

Checking and Corrective Action

- Monitoring to verify environmental performance and compliance.
- Maintaining non-conformance and corrective and preventative action procedures.

Management Review

- Periodic review by CNL's management to ensure the ongoing suitability, adequacy and effectiveness of the EMS.

As mentioned in Section 3.9, CNL maintains a comprehensive EMP at the CRL property. The EMP operates under the direction of CNL's Environmental Protection Program to achieve the following primary objectives:

- To assess the level of risk on human health and safety, and the potential biological effects in the environment of the contaminants of concern arising from the facility.
- To demonstrate compliance with limits on the concentration and/or intensity of contaminants and physical stressors in the environment or their effect on the environment.
- To check, independently of effluent monitoring, on the effectiveness of contaminant and effluent control, and provide public assurance of the effectiveness of containment and effluent control.
- Provide an indication of unusual or unforeseen conditions that might require corrective action or additional monitoring.
- To verify predictions made in the Environmental Risk Assessment (ERA), Derived Release Limit (DRL) model, and/or environmental assessments, refine the models used, and reduce the uncertainty in predictions made by these assessments and models.

The EMP is also designed to provide data required to support site restoration programs, site operations, or to plan for future stages of the site lifecycle (e.g., decommissioning); to provide resources and data that can be of value during the response to an accident or upset, and in the recovery from such an event; to demonstrate due diligence; and to meet stakeholder commitments. The design of the EMP takes into account the facilities and processes at the CRL property, actual emissions from the site at present and in the past, the environmental pathways leading to radiation dose to critical groups, as well as various other scientific, historic, and public considerations. The EMP for the CRL property will be expanded to include monitoring and sampling locations for the NSDF Project.

The NSDF Project Environmental Protection Plan (EPP) will establish practices for safe and environmentally sound management of the facility during construction. This plan will establish practices and performance criteria to prevent unacceptable dispersal of radioactive and non-radioactive materials through environmental pathways and provides mechanisms for early detection of releases of radioactivity, as well as monitoring for both radioactive and non-radioactive emissions. This plan will also include information on how long-term behaviours of the waste are evaluated with respect to environmental protection.

3.13.2.3 Waste Management Program

Waste Management Program includes requirements and processes to provide that CNL activities that involve planning for, handling, processing, transporting, storage and disposal of wastes are performed in a manner that complies with applicable regulatory and license requirements and protects workers, the public and the environment. This Program will integrate the requirements for waste producers and Waste Operations authorities. The Waste Management Plan at CRL includes identification of waste inventory and the characteristics of the waste (radiological and hazardous non-radiological), waste segregation waste packaging and transfer requirements, and the plan for storage or disposal of the wastes. As mentioned in Section 3.8, the Waste Management Plan developed for the NSDF Project provides the plan for managing the waste generated during the construction, operations, and decommissioning of the NSDF in accordance with CRL waste management requirements.

3.13.2.4 Occupational Safety and Health Program

Canadian Nuclear Laboratories' Occupational Safety and Health Program is designed to provide for the protection of workers and public health and safety in relation to CNL activities. Canadian Nuclear Laboratories and its contactors will meet all applicable health and safety legislative requirements. Canadian Nuclear Laboratories requires that contractors and their subcontractors maintain a level of safety equivalent to that of CNL employees while on-site.

All activities related to the NSDF Project will be covered by either CNL's work permits with completed Radiological Safety Assessments, as required, or by approved work procedures. A Work Permit System for all non-routine work involving potential health and safety hazards provides that hazards are evaluated and appropriate protective measures taken.

3.13.2.5 Emergency Preparedness Program

Emergency Preparedness Program comprises planning and response elements to provide that processes are in place to control and mitigate the consequences of an emergency (whether related to a nuclear/radiological or conventional incident) both on- and off-site. In accordance with the Ontario Nuclear Emergency Plan, the program includes infrastructure, assigned response staff and other resources, and periodic exercises to test and demonstrate emergency preparedness. The Emergency Preparedness Program takes into consideration guidance provided in the CNSC's Nuclear Emergency Preparedness and Response document (CNSC 2016).

3.13.2.6 Nuclear Criticality Safety Program

Nuclear Criticality Safety Program is intended to prevent criticality accidents through appropriate design, analysis, operations, and decommissioning of facilities involving fissionable materials. The program applies to activities involving the use, processing, transfer, storage and disposal of fissionable materials. It requires that criticality safety analysis be conducted and that processes and procedures be established to provide assurance that a sufficient safety margin is established. The Nuclear Criticality Safety Program takes into consideration recommendations and guidance provided in the Federal Nuclear Emergency Plan (Health Canada 2014).

3.13.2.7 Physical Security Program

Physical Security Program is intended to provide continuous security coverage of the CRL property, in compliance with NSCA legislation and federal government security policy. The program provides physical protection against unauthorized access and malicious damage to nuclear facilities, non-nuclear facilities, and specified nuclear materials used, processed, stored or possessed by CNL at the site.

3.13.2.8 Nuclear Materials and Safeguards Management Compliance Program

Nuclear Materials and Safeguards Management Compliance Program is intended to manage and safeguard nuclear materials in CNL's custody, in compliance with applicable laws and standards. The program provides assurance that CNL's activities at CRL are meeting Canada's commitment under the Nuclear Non-proliferation Treaty.

3.13.2.9 Fire Protection Program

Fire Protection Program is dedicated to the delivery of a compliant Fire Protection program that will provide the highest level of fire and life safety to all CNL employees and facilities. The objectives of the Fire Protection Program include preventing fire losses, providing responsible fire protection management, demonstrating compliance to applicable fire protection codes and standards, and providing reliable facilities from a fire protection perspective. The Fire Protection Program provides services including developing fire prevention processes and conducting fire safety inspections. Fire hazard analyses, code compliance reviews and fire protection screenings are also conducted as part of the program.

4.0 PUBLIC AND ABORIGINAL ENGAGEMENT ACTIVITIES

4.1 Introduction

Public and Aboriginal engagement is a key component of the environmental assessment process and reflects the corporate social responsibility of Canadian Nuclear Laboratories (CNL). This section of the Environmental Impact Statement (EIS) summarizes CNL's past and proposed public and Aboriginal engagement initiatives for the Near Surface Disposal Facility Project (the NSDF Project), including documentation of meetings, presentation materials, discussion topics and outcomes, and relevant agreements. These activities are intended to fulfil the requirements for public and Aboriginal engagement under the *Canadian Environmental Assessment Act, 2012* and the *Nuclear Safety and Control Act*.

This section reflects a summary of planned activities executed per CNL's established Public Information Program (AECL 2014) and the project-specific Aboriginal Engagement Report (CNL 2016).

4.2 Communications Objectives and Strategic Alignment

CNL recognizes that it must conduct its business in a manner that is both socially and environmentally responsible. One way CNL demonstrates this commitment is through its ongoing Public Information Program. The Public Information Program aims to inform groups about ongoing activities at CNL sites and the potential effects of these activities on the health and safety of workers, members of the public, First Nations and Métis communities and on the environment. The Public Information Program builds public awareness, understanding and a supportive appreciation of CNL's value and relevance to Canadians.

Engagement activities completed as part of CNL's ongoing Public Information Program are done in accordance with the *Public Information and Disclosure* (RD/GD-99.3, CNSC 2012) and the *Aboriginal Engagement* (REGDOC-3.2.2; CNSC 2016) regulation documents. CNL also regularly reviews the Public Information Program to incorporate input from the public and/or First Nations and Métis communities, to adapt to changing needs or circumstances, to accommodate new information, or in response to other factors. The program includes the following objectives to provide wide accessibility of fact-based information to the public and First Nation and Métis communities regarding CNL's activities, including the NSDF Project.

1) Initiate and maintain two-way communication channels between CNL, the public and First Nation and Métis communities to determine the best methods for communicating project information and to facilitate the receipt of input at appropriate junctures in the NSDF Project schedule.
2) Develop meaningful, user-friendly information and communication products geared for the public and First Nation and Métis communities, and provide accessible and current information on NSDF Project activities.
3) Demonstrate CNL's long-term commitment and approach to the reduction of Canada's nuclear legacy liabilities in a safe and cost effective manner.
4) Inform and educate the public and First Nation and Métis communities about nuclear decommissioning, environmental remediation and radioactive waste management.
5) Meet all regulatory-based communication and engagement requirements.

To meet these objectives, CNL has developed specific strategies to increase the effectiveness of the program so that public and Aboriginal engagement requirements for the NSDF Project are met. These strategies include:

- Presenting information in an easy to understand format through a variety of communications channels using targeted key messaging.
- Use of technical experts to communicate information through a variety of channel.
- Accomplishing all required activities in a timely manner.
- Providing various means for accessibility of information for use by public and First Nation and Métis communities.

A description of the engagement activities planned and completed for the NSDF Project is provided in Section 4.3. The description is divided into two categories; by engagement activities with the general public (Section 4.3.1) and engagement activities with First Nation and Métis communities (Section 4.3.2).

4.3 Project-specific Engagement Activities

4.3.1 Public Engagement

CNL's Public Information Program provides regular public engagement activities designed to keep local stakeholders and other interested parties informed about CNL's Chalk River Laboratories (CRL) property. CNL's engagement efforts focus primarily on the neighbouring communities, landowners and residents located closest to the CRL property (e.g., host communities, local government and non-governmental organization, CNL staff), but CNL also actively communicates with other interested parties.

CNL has developed a variety of communication tools to effectively and meaningfully communicate with stakeholders for the NSDF Project. The communication tools developed for the NSDF Project include:

- public information sessions (previously referred to as "open houses");
- presentations;
- poster boards;
- advertising;
- proactive and by request project site visits;
- public events;
- employee information sessions;
- proactive media engagement;
- newsletters;
- web page content;
- social media presence via Twitter and Facebook;
- fact sheets; and,
- detailed written responses to stakeholder questions.

4.3.1.1 Public Participation Activities Completed to Date

4.3.1.1.1 Public Information Sessions

Public information sessions are an opportunity for CNL to inform, educate and discuss the NSDF Project and the environmental assessment process with the host communities surrounding the CRL property. CNL staff and technical experts were available at all public information sessions to inform the public about the NSDF Project and to answer any questions raised by the public. CNL also developed poster boards with the intent to educate and prompt discussion about the NSDF Project. Poster boards were developed for the following topics and are provided in Appendix 4.0-1[1]:

For the June and July public information sessions:

- What is an environmental assessment?
- Valued Components;
- Cultural Resource Management;
- Project Description;
- Graphic Representation of the NSDF Project;
- Proposed Location of the NSDF Project; and,
- Biodiversity.

Additionally for the October public information sessions:

- Site Revitalization (how CNL intends to build new laboratories and revitalize its organization);
- Proposed waste solution (overview of the NSDF Project);
- Site Selection (information about why the East Mattawa Road (EMR) site was chosen as the preferred site); and,
- What will the facility look like?

The public information sessions were advertised in a variety of media to increase public awareness (Appendix 4.0-2). Advertising for the June and July public information sessions began in June 2016 on the www.cnl.ca/nsdf website and on the radio. Advertising began in early October on the www.cnl.ca/nsdf website and on the radio (Star 96.7); paid newspaper advertisements ran in three community newspapers in weeks leading up to the Information Sessions. A flyer insert was published as well, with a reach of approximately 30,000 households across the local region. Facebook advertising via a "Boosted Post" geo located CNL's online advertising to the locations of each of the seven public information sessions. Dates for the June and July public information sessions were also were provided in the June 2016 edition of CONTACT (local newsletter, Section 4.3.1.1.7).

---

[1] Public Information Sessions for the NSDF Project were held jointly with the NPD Project. Materials in the appendices include information referencing both projects.

CNL also ran radio advertisements from October 2 to 15, 2016. The advertisement was a public service announcement advertising the information sessions and ran 50 times over the two week period. The advertisement was aired on STAR 96.7, a local country music station, which that serves the Renfrew and Pontiac Counties and parts of Ottawa. STAR 96.7 reaches approximately 40,000 listeners each week.

Fourteen public information sessions were scheduled, advertised and held throughout 2016 (Table 4.3.1-1). The locations for the public information sessions were chosen based on proximity to the CRL property and population size. A feedback form was available at all public information sessions to encourage participants to provide written feedback on the NSDF Project (Appendix 4.0-3).

The third round of public information sessions are scheduled for April and May of 2017, to align with the Canadian Nuclear Safety Commission (CNSC) public consultation period on the EIS. Notification methods and locations are planned to be similar as undertaken for the first two rounds of information sessions described above.

Table 4.3.1-1: Public Information Sessions Dates and Locations

Location	Date	Times	Attendance	Comments Received
Rapides-des-Joachims, Quebec	June 20, 2016	6:00 p.m. to 9:00 p.m.	7	6
	October 17, 2016	6:00 p.m. to 8:00 p.m.	10	6
Deep River, Ontario	June 21, 2016	6:00 p.m. to 9:00 p.m.	17	2
	October 18, 2016	6:00 p.m. to 8:00 p.m.	22	6
Stonecliffe, Ontario	June 22, 2016	6:00 p.m. to 9:00 p.m.	2	0
	October 19, 2016	6:00 p.m. to 8:00 p.m.	5	0
Sheenboro, Quebec	June 29, 2016	6:00 p.m. to 9:00 p.m.	29	10
	October 20, 2016	6:00 p.m. to 8:00 p.m.	12	2
Pembroke, Ontario	July 6, 2016	6:00 p.m. to 9:00 p.m.	13	10
	October 24, 2016	6:00 p.m. to 8:00 p.m.	20	8
Petawawa, Ontario	July 7, 2016	6:00 p.m. to 9:00 p.m.	17	7
	October 27, 2016	6:00 p.m. to 8:00 p.m.	9	2
Chalk River, Ontario	July 12, 2016	6:00 p.m. to 9:00 p.m.	11	10
	October 26, 2016	6:00 p.m. to 8:00 p.m.	18	4

4.3.1.1.2 Environmental Stewardship Council Meetings

In 2006, CNL established the Environmental Stewardship Council (ESC) for CRL. The function of the ESC is to provide opportunity for face-to-face meetings and to build an enhanced working relationship through effective dialogue with the public and First Nations and Métis communities. A list of the member organizations of the ESC is provided in Appendix 4.0-4.

At each meeting, ESC members are presented with information about CNL, CNL's environmental practices, and are given the opportunity to ask questions and discuss the information presented. Environmental Stewardship Council members are also asked to distribute meeting information to their respective constituents. This open dialogue and sharing of information is very important to CNL so that perspectives from the closest neighbours, non-governmental organizations and First Nation and Métis communities are heard and considered in how CNL carries out their missions. Meeting notes are taken at each meeting, recording all questions and action items.

The NSDF Project has been discussed at four ESC meetings to date, as listed below. Each of these meetings included an opportunity for members to ask questions and raise any concerns regarding the NSDF Project.

- On October 29, 2015, ESC members were introduced to CNL's near and longer term plans including a high-level description of the NSDF Project. A copy of the meeting agenda is provided in Appendix 4.0-5.
- On March 24, 2016, the ESC was further briefed on the NSDF Project, the facility's role in the CRL site revitalization, the overall environmental assessment process, and on the two proposed site locations being evaluated for the NSDF Project. A copy of the meeting agenda and presentation is provided in Appendix 4.0-6.
- On June 16, 2016, the ESC meeting was held at the CRL property where attendees were presented with an overview of the NSDF Project. Attendees also had the opportunity to tour the two proposed site locations for the NSDF Project. A copy of the meeting agenda and presentation is provided in Appendix 4.0-7.
- On October 13, 2016, the ESC meeting was held at the Best Western Pembroke Inn where the attendees were presented with an update on the NSDF Project. A copy of the meeting agenda is provided in Appendix 4.0-8.

The next scheduled ESC meeting is planned for March 23, 2017, which will include an update on the NSDF Project.

4.3.1.1.3 Proactive and Upon Request Site Visits

CNL periodically hosts by invitation or request site visits to provide an opportunity for open dialogue with stakeholders. For the NSDF Project, five site visits have been completed to date, including the ESC tour on June 16, 2016 described in the above Section 4.3.1.1.2.

World Nuclear University Site Visit – July 15, 2016

The World Nuclear University (WNU) is an organization that provides training to young professionals in the nuclear industry. This includes the WNU Summer Institute, which is an intensive six-week programme for future nuclear leaders across the globe that is held annually in different locations.

In 2016, the WNU Summer Institute was hosted in Ottawa. On July 15, 2016, 80 nuclear industry representatives and students toured CNL's CRL property. Participants received a detailed presentation and poster board session on the NSDF Project. Due to inclement weather, the participants were unable to visit the two proposed site locations for the NSDF Project. Comment cards on the NSDF Project were provided to the participants to solicit international nuclear industry feedback. A copy of the agenda, presentation and feedback form for the WNU site visit are provided in Appendix 4.0-9.

NGO Site Visit – July 26, 2016

Northwatch, the Canadian Environmental Law Association (CELA), and the Concerned Citizens of Renfrew County, represent three non-government organizations (NGO) interested in the environmental assessment activities for the NSDF Project. Northwatch and CELA provided comments on the *Project Description: Near Surface Disposal Facility at Chalk River Laboratories* (CRL 2016) submitted to the CNSC in March 2016.

A site visit for Northwatch, CELA and the Concerned Citizens of Renfrew County was completed on July 26, 2016. Representatives of these groups received a presentation that covered an overview of CNL, the environmental assessment process and an overview of the NSDF Project. Questions from the representatives focused on the waste acceptance criteria for the engineered containment mound (ECM), origin of wastes to be placed in the ECM, the performance of the NSDF Project over several hundred years, the regulatory process for the NSDF Project and how to access information required for the environmental assessment process.

The representatives also visited the two proposed site locations for the NSDF Project. While in the field, the representatives were provided with more details about the biodiversity of the two sites and the cultural resource management program at CNL. Questions from the representatives primarily focused on long-term groundwater monitoring. A copy of the agenda, presentation and meeting notes for the NGO site visit are provided in Appendix 4.0-10.

Organization of Canadian Nuclear Industries Suppliers' Day – September 8, 2016

The Organization of Canadian Nuclear Industries (OCNI) Suppliers' day was held at Chalk River Laboratories. The event provided an opportunity for CNL to engage with representatives of more than 45 companies throughout the Canadian Nuclear Supply Chain. A presentation on decommissioning and waste management initiatives at CNL informed the participants, individuals with knowledge and expertise of the nuclear industry, about the plan for the NSDF Project.

CNL Site Tour – NWMD&ER Conference - September 15, 2016

CNL hosted a tour for a group from the Canadian Nuclear Society's Nuclear Waste Management, Decommissioning and Environmental Restoration (NWMD&ER) Conference. The tour included a presentation on the NSDF project given by Jim Buckley, Director, Low Level Waste Facilities. Nineteen individuals attended the tour. The presentation is provided in Appendix 4.0-11.

4.3.1.1.4 Public Events

CNL representatives attend local community events, where appropriate, as another opportunity to initiate two-way communication with the public and to inform and educate the public about the NSDF Project. Specifically, CNL was invited to present at the Rotary Club of North Renfrew's Annual Dinner on July 20, 2016. CNL's President and Chief Executive Officer, Mark Lesinski, presented on CNL's Vision 2026 with a focus on the NSDF Project. There were no questions or comments related to the NSDF Project. A copy of the presentation is provided in Appendix 4.0-12. September 23 through 25, 2016, CNL attended the Petawawa showcase, a home, consumer and leisure showcase drawing approximately 10,000 visitors, and presented informational posters on the NSDF Project. This showcase provided another opportunity to have one on one interaction with community members (Appendix 4.0-13).

4.3.1.1.5 Employee Information Sessions

Employee information session were held on July 20, November 16 and November 17, 2016 for the NSDF Project to reach internal stakeholders. Similar to the public information sessions, various communications products were used (e.g., poster boards, fact sheets, myCNL articles, Voyageur newsletter) and subject matter experts were available to answer questions. Thirty four employees attended the information session in July and 45 additional employees attended the two sessions in November. A feedback form was made available to employees at all of the sessions (Appendix 4.0-3) and no comments were received.

4.3.1.1.6 Media Coverage

The local media reported on the NSDF Project fourteen times between May and December 2016, as documented in the Table 4.3.1-2. Local media coverage of the NSDF Project was generally favourable and contained facts informed by CNL's communication products and subject matter experts. A copy of the media coverage for the NSDF Project is provided in Appendix 4.0-14.

It should be noted that the four letters to the editor noted here did not support the NSDF Project. The author of the first letter also attended two public information sessions, discussed their views on the NSDF Project Description and formally provided comments to the CNSC. The other authors of letters also attended information sessions. CNL collaborated with these stakeholders to establish a workshop agenda and date for a Technical Meeting designed to permit these authors direct access to NSDF Project subject matter experts for a Q&A session and discussion. This Technical Meeting was held on January 19, 2017.

Table 4.3.1-2: Media Coverage for the NSDF Project (May to December 2016)

Date	Article	Title of Publication
May 10, 2016	In Other News	WNN Daily Progress
May 12, 2016	Plans in works for decommissioning and waste disposal at CNL	MyFM 104.9 Radio
May 18, 2016	CNL submits projects for EA approval	North Renfrew Times
June 29, 2016	"Disposal" projects will have long term consequences	Letter to the Editor – North Renfrew Times
July 7, 2016	CNL unveils two projects	Pembroke Observer
July 20, 2016	Public Information Sessions on disposal project	North Renfrew Times
October 12, 2016	County aims for 3%	North Renfrew Times
October 12, 2016	CNL to hold new information sessions	North Renfrew Times
October 14, 2016	Public Consultation Needed	Letter to the Editor - Pembroke Observer
November 2, 2016	CNL moving forward on decommissioning projects	North Renfrew Times
November 9, 2016	Questions Raised over CNL Waste Projects	North Renfrew Times
November 9, 2016	The devil will be in the details	Letter to the Editor - North Renfrew Times
November 23, 2016	Where is vision for CNL future?	Letter to the Editor - North Renfrew Times
December 7, 2016	Is there "reason"	Letter to the Editor - North Renfrew Times

4.3.1.1.7 Newsletters

The CONTACT newsletter is published and mailed to 55,000 residences in the Renfrew and Pontiac Counties and is available on www.cnl.ca/nsdf. This publication informs the reader on activities undertaken at CNL's various sites and profiles CNL's community activities. The June 2016 issue of CONTACT included a description of the NSDF Project and advertisements for the public information sessions. A copy of the June 2016 issue of CONTACT is provided in Appendix 4.0-15. A future edition of the CONTACT newsletter will be available in spring 2017.

4.3.1.1.8 Web Page Content

Web content for the NSDF Project was prepared and a unique, project-specific web page URL was established at www.cnl.ca/nsdf (Appendix 4.0-16). Visitors to the site are able to download the fact sheet and Project Description for the NSDF Project. Visitors can also share feedback on the NSDF Project through an online submission form. There has been no feedback submitted via the online submission form to date. This site will continue to be updated as the NSDF Project continues.

4.3.1.1.9 Fact Sheets

Project-specific fact sheets were prepared for use in conjunction with a number of other tactics. The fact sheet for the NSDF Project is available for download on the project website and was available at the public information sessions, public events and employee information session. A copy of the initial NSDF Project fact sheet and a revised fact sheet is provided in Appendix 4.0-17.

4.3.1.1.10 Other Stakeholder Engagement

Renfrew County Council Meeting

On December 12, 2016, CNL hosted the Renfrew County Council. The meeting included an overview presentation of CNL, as well as a specific presentation on the NSDF Project. It provided an opportunity to provide updated information to local elected officials and answer questions (see Appendix 4.0-18).

Ottawa Valley Economic Development Committee Meeting

The Ottawa Valley Economic Development Committee is comprised of economic development officers from the local municipalities, as well key regional employers (e.g., Garrison Petawawa, CNL and Algonquin College). Ottawa Valley Economic Development holds bi-monthly meetings to discuss economic issues and opportunities throughout Ottawa Valley and Eastern Ontario. On December 15, 2016 CNL hosted the meeting, which included a presentation on the NSDF Project from the project leads (see Appendix 4.0-19).

Meeting and Project Briefing with Pontiac MP

At the request of the Member of Parliament (MP) for the Riding of Pontiac (Will Amos), CNL attended the MP's constituency office in Campbell's Bay, Quebec on December 21, 2016 (see Appendix 4.0-20). The meeting briefed the MP on the NSDF Project and enabled the MP to discuss the project with the project leads and other subject matter experts. A follow-up meeting was held on February 9, 2017.

Old Fort William Cottagers' Association

In response to a letter provided as feedback at public information session held in Sheenboro, CNL prepared detailed answers to a number of questions raised by a community group of seasonal residents, the Old Fort William Cottagers' Association (see Appendix 4.0-21). CNL also offered the group the opportunity for a site tour and NSDF Project-specific presentation.

4.3.1.2 Summary of Issues Raised and Responses Provided

The following sections describe the general feedback received to date on the NSDF Project. Feedback is categorized by stakeholder – public and industry – to prevent a bias from the industry feedback and to better understand where industry and public concerns divide. A more detailed description of the feedback received to date and CNL's responses are provided in Appendix 4.0-22.

4.3.1.2.1 Public Feedback

The initial feedback received gives valuable insight into what issues are important to the public, enabling CNL to respond to and incorporate the issues of the local community and the broader public into the planning stages for the NSDF Project.

The majority of feedback was received through the public information sessions with a small number of respondents submitting comments through mail and email; no comments have been received through the online submission form as of yet.

The main themes of the feedback received to date for the NSDF Project include:

- engineering containment mound construction materials (clay);
- seismic qualifications vs. seismic activity at the two proposed sites;

- water quality monitoring for groundwater and the Ottawa River;
- waste acceptance criteria;
- future impact of natural disasters and climate change on the project; and,
- origins of material for disposal in the NSDF facility.

CNL has received 51 written questions from the public and/or CNL staff through public information sessions, mail, telephone or email. Of these, 24 were received between April and July of 2016, and 27 more between August and December 2016. These questions, categorized by theme, are illustrated in Figure 4.3.1-1.

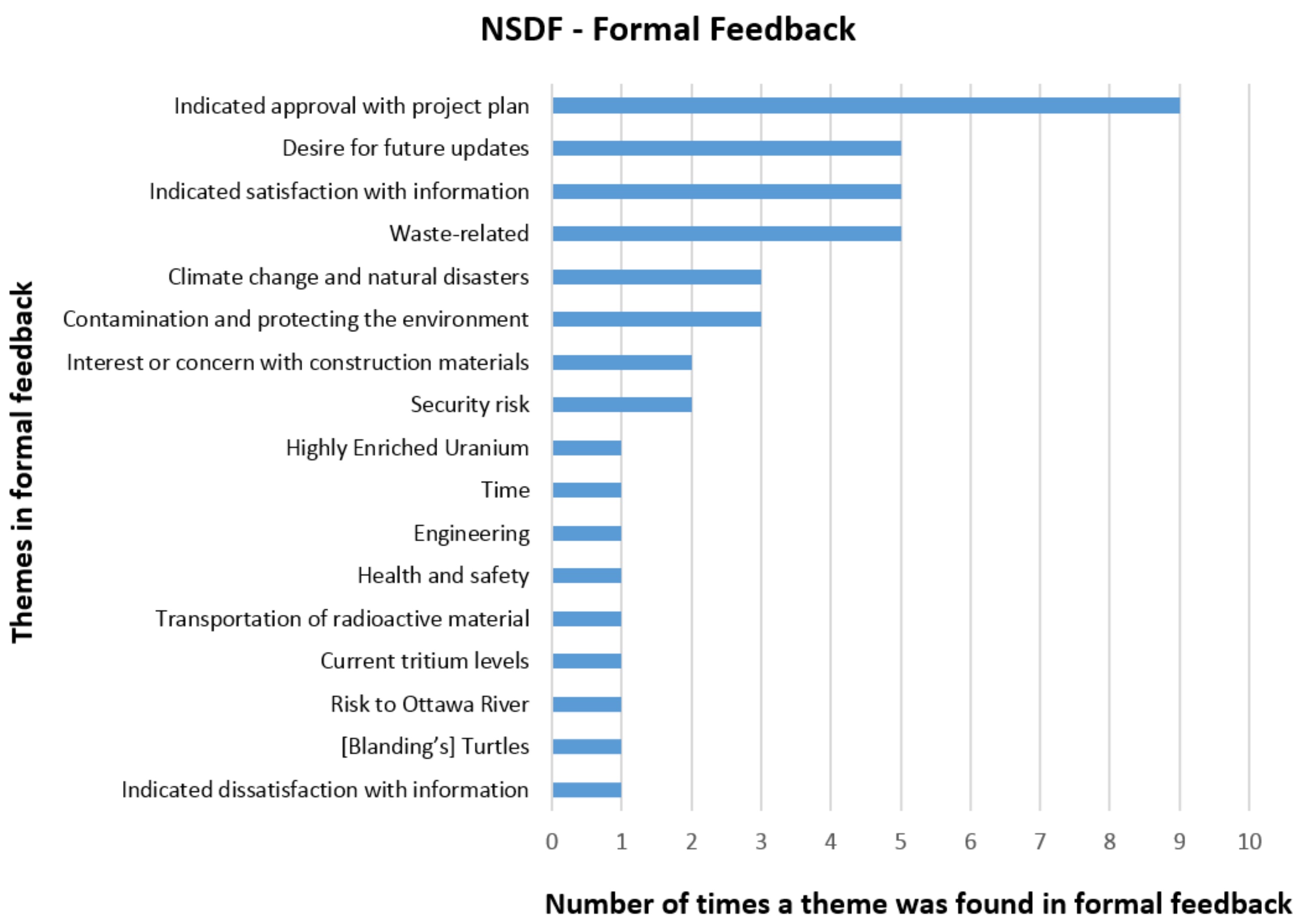


Figure 4.3.1-1: Written Comments Received for the Near Surface Disposal Facility Project.

4.3.1.2.2 Industry Feedback

The WNU site visit in July and the subsequent NWMD&ER Conference tour visit in October provided opportunities to solicit industry feedback. Individuals completed feedback forms after visiting the CRL property and learning about NSDF Project. Generally, the comments received from the WNU site visit participants were supportive, with some concern that the public might not fully comprehend the NSDF Project, and the technology behind it as a solution for the low level waste generated at CNL. The comments received on the proposed NSDF from the NWMD&ER Conference guests indicated satisfaction with the information provided by the subject matter experts at CNL, and interest in subject areas such as waste, safety, geography and construction materials.

Figure 4.3.1-2 shows the distribution of themes in the comments received from the NWMD&ER site visit participants.

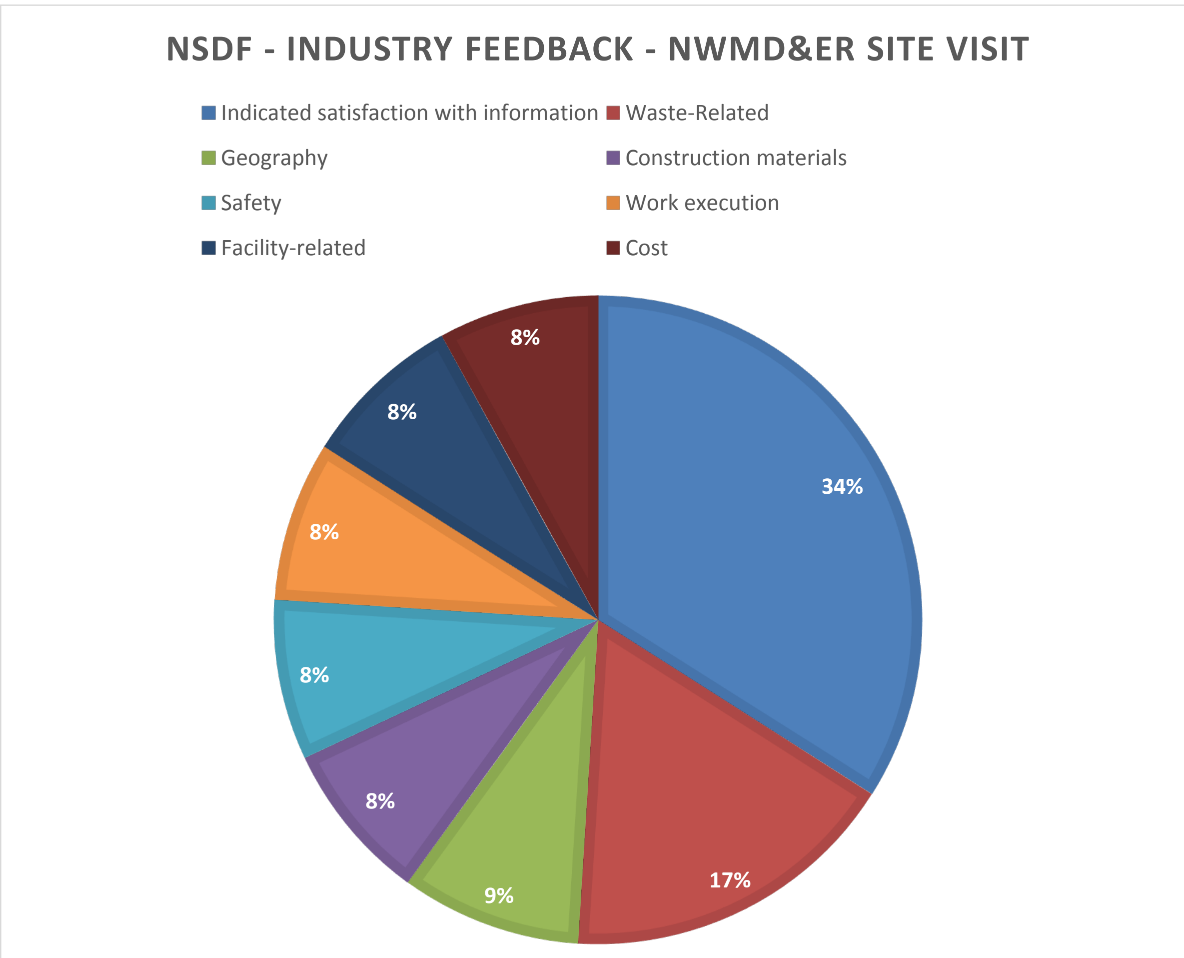


Figure 4.3.1-2: Feedback Received from Nuclear Waste Management, Decommissioning and Environmental Restoration Conference Guests

Figure 4.3.1-3 shows the distribution of themes in the comments received from the WNU site visit participants.

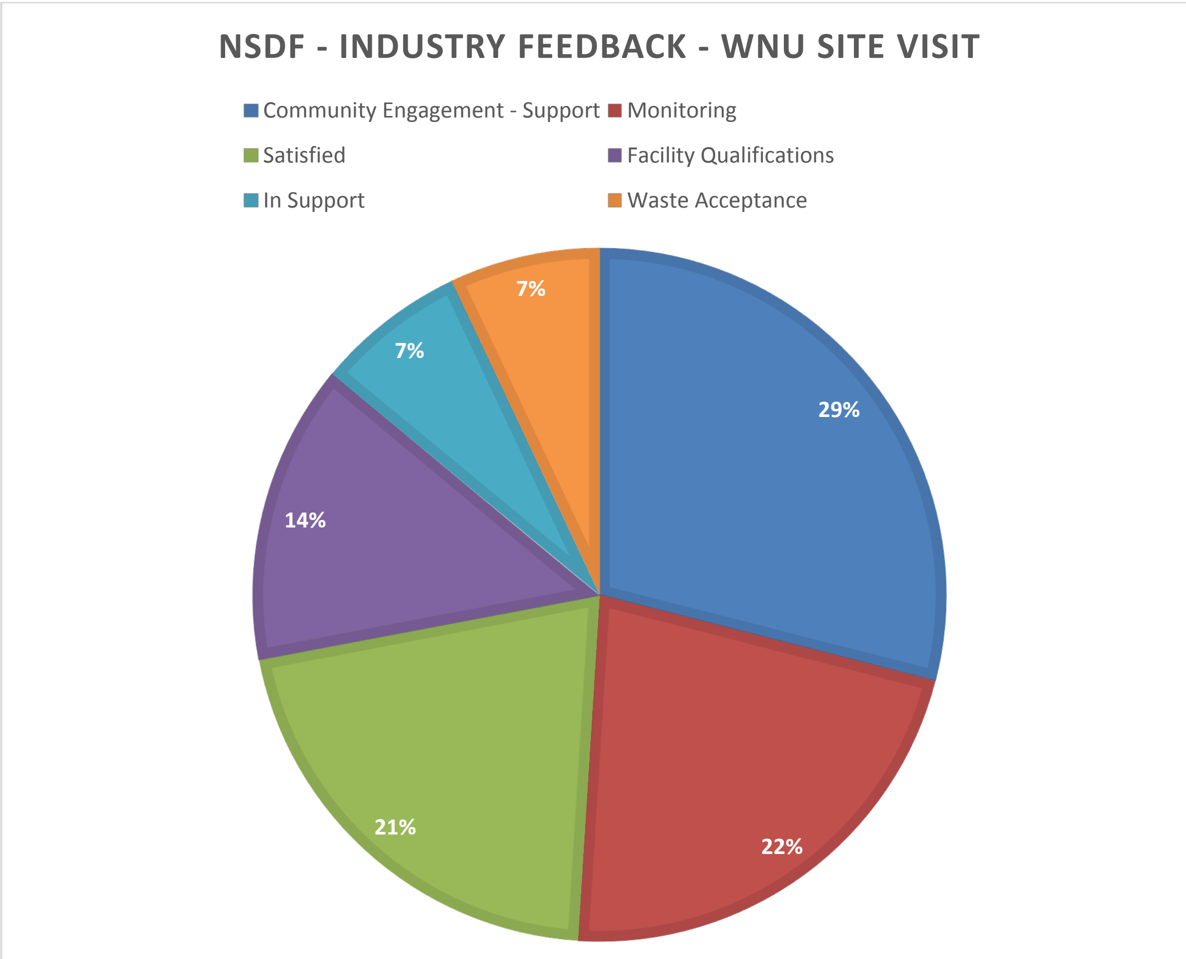


Figure 4.3.1-3: Feedback Received from World Nuclear University Site Visit Participants

4.3.2 Aboriginal Engagement

As described in Section 4.2, CNL operates an ongoing Public Information Program to inform groups about ongoing activities at CNL sites and the potential effects of these activities on the public, First Nation and Métis communities and on the environment. This Public Information Program forms the basis of communication efforts with First Nation and Métis communities and helps to direct the establishment of long-term mutually beneficial working relationships with their communities in proximity to CNL sites.

In consultation with the CNSC, and using tools provided through Aboriginal and Treaty Rights Information System (ATRIS), CNL identified a proposed list of First Nation and Métis communities and organizations with potential interest in the NSDF Project. The proposed list and a brief rationale for including each First Nation and Métis communities and organizations engaged for the NSDF Project is provided in Table 4.3.2-1. This proposed list is based on a preliminary assessment of existing and available information on Aboriginal and treaty rights in the vicinity of the NSDF Project and is subject to change based on information and dialogue with the identified groups.

Table 4.3.2-1: First Nation and Métis Communities Selected for NSDF Project Engagement Activities

First Nation and Métis Community or Group	Location	Identification Rationale
Algonquins of Ontario (AOO)	The AOO are comprised of 10 Algonquin communities: ■ Antoine ■ Algonquins of Pikwàkanagàn First Nation ■ Bonnechere ■ Greater Golden Lake ■ Kijicho Manito Madaouskarini (Bancroft) ■ Mattawa/North Bay ■ Ottawa ■ Shabot Obaadjiwan (Sharbot Lake) ■ Snimikobi (Ardoch) ■ Whitney and Area	■ Comprehensive Land Claim ■ Accepted for Negotiations with Self-Government ■ Framework Agreement (Signed) ■ Established CNL relationship (member of ESC)
Algonquins of Pikwàkanagàn	■ Member of the AOO ■ Pikwàkanagàn is adjacent to Golden Lake, Ontario within the County of Renfrew; the Algonquins of Pikwàkanagàn sit on CNL's ESC	■ Comprehensive Land Claim ■ Accepted for Negotiations with Self-Government ■ Framework Agreement (Signed) ■ Established CNL relationship (member of ESC)
Algonquin Anishinabeg Nation Tribal Council (Kitigan Zibi Anishinabeg First Nation and Eagle Village First Nation)	■ The Algonquin Anishinabeg Nation Tribal Council represents seven members in the protection and advancement of the Aboriginal rights issues and provision of assistance and services to the participating communities in advisory and technical fields ■ The Kitigan Zibi Anishinabeg First Nation adjacent to the Town of Maniwaki in the province of Quebec ■ Eagle Village First Nation – Kipawa adjacent to the Town of Temiscaming in the province of Quebec	■ Comprehensive Land Claim ■ Assertion of Rights
Métis Nation of Ontario	■ The North Bay Métis Council is a Community Council of the Métis Nation of Ontario and sits on CNL's ESC	■ Assertion of rights in the vicinity of the project ■ Established CNL relationship (member of ESC)

Table 4.3.2-1: First Nation and Métis Communities Selected for NSDF Project Engagement Activities

First Nation and Métis Community or Group	Location	Identification Rationale
Williams Treaties First Nations	■ Hiawatha First Nation is based out of the north side of Rice Lake in Peterborough County, Ontario ■ Beausoleil First Nation is in Cedar Point, Ontario ■ Alderville First Nation is in the south side of Rice Lake near Roseneath in Peterborough County, Ontario ■ Curve Lake First Nation is based out of two islands and a peninsula in Buckhorn Lake, 15 km north of Peterborough, Ontario ■ Chippewas of Georgina Island First Nation is in three islands in the south-eastern portion of Lake Simcoe adjacent to the Regional Municipality of York, Ontario ■ Chippewas of Rama First Nation is an Anishinaabe (Ojibway) First Nation located 90-minutes north of Toronto, on approximately 2,500 acres of interspersed land on the eastern shore of Lake Couchiching within the Township of Ramara, Ontario ■ The Mississaugas of Scugog Island First Nation is in Scugog Island in Lake Scugog adjacent to the Regional Municipality of Durham, Ontario	Historic treaty, NSDF Project is located within the lands covered by the Williams Treaties
Union of Ontario Indians	N/A	Umbrella organization that has members with potentially affected rights
Algonquin Nation Secretariat	N/A	Umbrella organization that has members with potentially affected rights

N/A = not applicable.

Engagement activities with First Nations and Métis communities in support of the project continue as the environmental assessment and Project planning activities progress. Continued updates have been provided to First Nations and Métis communities to share of information related to environmental assessment activities and findings based on community needs and/or level of interest.

4.3.2.1 Aboriginal Engagement Activities Completed

Engagement with First Nation and Métis communities and groups (as identified in Table 4.3.2-1) started in October 2015 and has continued to the date of this report's submission. The Aboriginal engagement activities completed to date are described in Table 4.3.2-2.

Table 4.3.2-2: Aboriginal Engagement Activities to Date

Date	Event/Activity	Attendance/Correspondence	Notes/Supporting Documentation
October 29, 2015	Environmental Stewardship Council Meeting – A brief overview of the NSDF Project within the context of a larger vision of the company was provided.	■ Algonquins of Pikwàkanagàn and Métis Nation of Ontario are members of CNL's ESC. No representatives or designates attended the meeting, however, meeting materials and notes were provided.	Meeting Agenda and Presentation (Appendix 4.0-5)
December 1, 2015	Algonquins of Pikwàkanagàn Site Visit – A brief overview of the NSDF Project within the context of a larger vision of the company was provided.	■ Chief, members of Council, and representatives of the band office attended.	Meeting Agenda and Presentation (Appendix 4.0-24)
March 24, 2016	Environmental Stewardship Council Meeting – A detailed overview of the NSDF Project was provided including potential sites for locating the NSDF.	■ Algonquins of Pikwàkanagàn and Métis Nation of Ontario are members of CNL's ESC. No representatives or designates attended the meeting, however, meeting materials and notes were provided.	Meeting Agenda and Presentation (Appendix 4.0-6)
June 2, 2016	NSDF – Introductory discussion with Métis Nation of Ontario	■ Region 5 Consultation Committee James Wagar ■ Steven Sarrazin ■ Métis Nation of Ontario (MNO) to share single point of contact (SPOC) and example work plan	Website link (Appendix 4.0-16)
June 16, 2016	Environmental Stewardship Council Meeting – ESC was hosted at the CRL property where the group was provided a thorough presentation on the NSDF Project and a tour of the two proposed site locations.	■ Attendance Métis Nation of Ontario ■ Algonquins of Pikwàkanagàn are members of CNL's ESC. No representatives or designates attended the meeting, however, meeting materials and notes were provided	Meeting Agenda and Presentation (Appendix 4.0-7) Poster Boards (Appendix 4.0-1)

Table 4.3.2-2: Aboriginal Engagement Activities to Date

Date	Event/Activity	Attendance/Correspondence	Notes/Supporting Documentation
July 15, 2016	Project Introductory Letter and request for community input on any potential adverse effects from project activities.	■ Algonquin Nation Secretariat ■ Williams Treaties First Nation – Georgina Island ■ Williams Treaties First Nation – Mississaugas of Scugog Island ■ Williams Treaties First Nation – Alderville First Nation ■ Eagle Village First Nation ■ Williams Treaties First Nation – Chippewa Indians of Rama First Nation ■ Kitigan Zibi Anishinabek First Nation Williams Treaties First Nation – Hiawatha ■ Williams Treaties First Nation – Curve Lake First Nation ■ Williams Treaties First Nation – Beausoleil Métis Nation of Ontario ■ Algonquins of Ontario consultation Office ■ Algonquins of Ontario - Algonquins of Pikwàkanagàn) ■ Algonquin Anishinabeg Nation Tribal Council	Introductory letter (Appendix 4.0-23)
July 20, 2016	Métis Nation of Ontario Mattawa/Lake Nipissing traditional territory consultation committee meeting with CNL	■ MNO Mattawa/Lake Nipissing Métis Traditional Territory Consultation Committee: Roger Rose, Councillor, MNO Mattawa Métis Council; Marc Laurin, President, MNO North Bay Métis Council; Maurice Sarrazin, Chair, MNO Sudbury Métis Council; Richard Sarrazin, President, MNO Sudbury Métis Council, Region 5 Captain of the Hunt ■ MNO Lands, Resources & Consultation Branch Staff: Steven Sarrazin, Coordinator, Lands and Resources; Austin Acton, Consultation Assessment Coordinator	Poster Boards (Appendix 4.0-1) Meeting Agenda and Presentation (Appendix 4.0-25)
August 10, 2016	Algonquins of Ontario (AOO) Consultation Office and Technical Staff Information Session	■ AOO representatives: Megan Aikens, Communications and Policy Strategist, Ethan Huner, Senior Resource Technician, Jim Hunton, Technical Advisor and Environment Land Use Planner to the AOO, Lucas Tyukodi, Biologist/Resource Technician	AOO Agenda (Appendix 4.0-26)

Table 4.3.2-2: Aboriginal Engagement Activities to Date

Date	Event/Activity	Attendance/Correspondence	Notes/Supporting Documentation
August 19, 2016	Telephone call from Kitigan Zibi Anishinabeg First Nation to CNL	■ Pat Quinn, CNL and Melissa Olmstead, Kitigan Zibi Anishinabeg First Nation	Telephone call indicated the First Nation had received the initial letter and were interested in more project information as it becomes available
August 19, 2016	Telephone call from CNL to Algonquins of Pikwàkanagàn	■ Nicole LeBlanc, CNL and Alana Hein and Chief Kirby Whiteduck, Algonquins of Pikwàkanagàn	Follow up telephone call to introductory project letter
October 24, 2016	Telephone call from CNL to Kitigan Zibi Anishinabeg First Nation	■ Nicole LeBlanc, CNL and Chief Jean Guy Whiteduck/Melissa Olmstead, Kitigan Zibi Anishinabeg First Nation	Telephone call offering updated information in response to Kitigan Zibi Anishinabeg First Nation's earlier request
October 24 to 26, 2016	Follow up telephone call to project introductory letter	■ CNL ■ Algonquins of Anishinabeg Nation Tribal Council (AANTC) ■ Eagle Village First Nation ■ Alderville First Nation (Williams Treaties First Nation) ■ Chippewas of Georgina Island (Williams Treaties First Nation) ■ Mississaugas of Scugog Island (Williams Treaties First Nation) ■ Alderville First Nation (Williams Treaties First Nation) ■ Chippewas of Rama First Nation (Williams Treaties First Nation) ■ Hiawatha First Nation ■ (Williams Treaties First Nation) ■ Curve Lake First Nation ■ (Williams Treaties First Nation) ■ Beausoleil First Nation ■ (Williams Treaties First Nation) ■ Algonquins of Pikwàkanagàn ■ Union of Ontario Indians ■ Algonquin Nation Secretariat	Follow up phone call to project introductory letter inquiring if there was further interest in project information or meeting with CNL
November 1, 2016	Telephone call from CNL to AOO	■ Pat Quinn, CNL ■ Jim Hunton, AOO	n/a
November 1, 2016	Email from CNL to AOO	■ Pat Quinn, CNL ■ Jim Hunton, AOO	Email regarding project information and, in particular, archeological information
November 3, 2016	Telephone call from AOO to CNL	■ Janet Stavinga, AOO ■ Pat Quinn, CNL	n/a
November 3, 2016	Telephone call from CNL to AOO	■ Pat Quinn, CNL ■ Janet Stavinga, AOO	n/a

Table 4.3.2-2: Aboriginal Engagement Activities to Date

Date	Event/Activity	Attendance/Correspondence	Notes/Supporting Documentation
November 1 to 9, 2016	Email correspondence between AOO and CNL	■ Janet Stavinga, AOO ■ Pat Quinn, CNL	Email regarding projects, field work support and participation by AOO, and, in particular, archeological information
November 1, 2016	Voicemail from CNL to Mattawa Métis Council	■ Margot Thompson, CNL, left voicemail with Melanie Rose, Mattawa Métis Council	Left voicemail that followed up on the Mattawa Métis Council's request for Chimney Swift video and with offer to provide an expert in species at risk to come present to the council
November 10, 2016	Letter with updated project information and request for community input on potential project impact	■ CNL ■ Algonquins of Anishinabeg Nation Tribal Council (AANTC) ■ Eagle Village First Nation ■ Kitigan Zibi Anishinabeg First Nation ■ Alderville First Nation (Williams Treaties First Nation) ■ Chippewas of Georgina Island (Williams Treaties First Nation) ■ Mississaugas of Scugog Island (Williams Treaties First Nation) ■ Alderville First Nation (Williams Treaties First Nation) ■ Chippewas of Rama First Nation (Williams Treaties First Nation) ■ Hiawatha First Nation (Williams Treaties First Nation) ■ Curve Lake First Nation (Williams Treaties First Nation) ■ Beausoleil First Nation (Williams Treaties First Nation) ■ Algonquins of Pikwàkanagàn ■ Union of Ontario Indians ■ Algonquin Nation Secretariat	See Appendix 4.0-27 for letters that were sent to identified First Nation communities. Updated project information in the form of new informational posters, as included in Appendix 4.0-1, were provided
November 14, 2016	Email from CNL to Kitigan Zibi Anishinabeg First Nation	■ Nicole LeBlanc, CNL ■ Melissa Olmstead, Kitigan Zibi Anishinabeg First Nation ■ Linda Dwyer, Kitigan Zibi Anishinabeg First Nation	Email enclosing electronic copies of updated project information in response to request; discussion of meeting/visit dates

Table 4.3.2-2: Aboriginal Engagement Activities to Date

Date	Event/Activity	Attendance/Correspondence	Notes/Supporting Documentation
November 16, 2016	Email from Chippewas of Rama First Nation to CNL	■ Holly Nolan on behalf of Chief Rodney Noganosh, Chippewas of Rama First Nation ■ Pat Quinn, CNL	Email from Chippewas of Rama First Nation indicating they had forwarded project information to Karry Sandy-Mackenzie, Williams Treaties First Nations Process Coordinator
December 1, 2016	Email to Curve Lake First Nation from CNL enclosing requested information	■ Melissa Dokis, Curve Lake First Nation ■ Nicole LeBlanc, CNL	Email enclosing requested information on the NSDF site – Stage 1,2,3 Archeological Assessments
December 5, 2016	Letter and documents sent to AOO from CNL	■ Pat Quinn, CNL ■ Janet Stavinga, AOO	See Appendix 4.0-28 for letter, which details information requested and received by the AOO
December 8, 2016	Email from CNL to Mattawa Métis Council	■ Margot Thompson, CNL ■ Melanie Rose, Mattawa Métis Council	Email following up with Mattawa Métis Council's expressed interest in the Chimney Swifts and referring where to find the videos of the Chimney Swifts that CNL had uploaded to YouTube
December 9, 2016	Email from Curve Lake First Nation to CNL	■ Melissa Dokis, Curve Lake First Nation ■ Nicole LeBlanc, CNL	Email acknowledging receipt of archeological information
December 15, 2016	Letter to Curve Lake First Nation from CNL enclosing requested information	■ Melissa Dokis, Curve Lake First Nation ■ Pat Quinn, CNL	See Appendix 4.0-29 for letter enclosing requested archaeological information on the NSDF project site.
December 15, 2016	Email from CNL to Karry Sandy McKenzie, Williams Treaties First Nations, Process Coordinator	■ Phil Shantz, Arcadis on behalf of CNL ■ Karry Sandy McKenzie	Email in response to Chippewas of Rama First Nation indicating they had forwarded project information to Karry Sandy-McKenzie, Process Coordinator for the Williams Treaties First Nation.
December 19, 2016	Email from CNL to MNO	■ Pat Quinn, CNL to Steven Sarrazin, Métis Nation of Ontario (MNO)	Email correspondence with respect to providing a letter with information

Table 4.3.2-2: Aboriginal Engagement Activities to Date

Date	Event/Activity	Attendance/Correspondence	Notes/Supporting Documentation
December 22, 2016	Letter to MNO from CNL	■ Marc Laurin, MNO North Bay Métis Council ■ Nelson Montreuil, MNO Mattawa Métis Council ■ Richard Sarrazin, MNO Sudbury Métis Council ■ Steven Sarrazin, MNO ■ James Wagar, MNO ■ Jim Buckley, CNL ■ Pat Daly, CNL ■ Nicole LeBlanc, CNL ■ Margot Thompson, CNL ■ Pat Quinn, CNL	See Appendix 4.0-30 for letter offering an opportunity to meet and an interest in more information from the MNO on any potential impacts of the projects
December 22, 2016	Telephone call from CNL to Kitigan Zibi Anishinabeg First Nation	■ Nicole LeBlanc, CNL ■ Linda Dwyer, Kitigan Zibi Anishinabeg First Nation	Telephone call to follow up from CNSC meeting of 2016 November 20 with respect to CNL having a meeting and presentation with Kitigan Zibi Anishinabeg First Nation
January 5, 2017	Email from CNL to Karry Sandy McKenzie, Williams Treaties First Nations, Process Coordinator	■ Phil Shantz, Arcadis on behalf of CNL	Email from CNL to Karry Sandy-McKenzie, Williams Treaties First Nations, Process Coordinator, requesting follow up
January 10, 2017	Letter from Algonquins of Pikwàkanagàn to CNL	■ Algonquins of Pikwàkanagàn CNL	See Appendix 4.0-31 for the letter to CNL from Pikwakanagan in response to CNL's letter of 2016 November 10, requesting a meeting in April.
January 12, 2017	Telephone call from CNL to Kitigan Zibi Anishinabeg Fist Nation	■ Nicole LeBlanc, CNL ■ Linda Dwyer, Kitigan Zibi Anishinabeg First Nation	Follow up telephone call to inquire about Kitigan Zibi Anishinabeg First Nation's interest (as indicated at the CNSC meeting of 2016 November 20) in having a meeting and presentation from CNL with respect to projects

Table 4.3.2-2: Aboriginal Engagement Activities to Date

Date	Event/Activity	Attendance/Correspondence	Notes/Supporting Documentation
January 12, 2017	Email from CNL to Kitigan Zibi Anishinabeg Fist Nation	■ Nicole LeBlanc, CNL ■ Linda Dwyer, Kitigan Zibi Anishinabeg First Nation ■ Melissa Olmstead, Kitigan Zibi Anishinabeg First Nation	Follow up email to inquire about Kitigan Zibi Anishinabeg First Nation's interest (as indicated at the CNSC meeting of 2016 November 20) in having a meeting and presentation from CNL with respect to projects
January 12, 2017	Telephone and email correspondence between Kitigan Zibi Anishinabeg Fist Nation to CNL	■ Nicole LeBlanc, CNL ■ Linda Dwyer, Kitigan Zibi Anishinabeg First Nation	Finalized interest in a 2017 April meeting and presentation from CNL to Kitigan Zibi Anishinabeg First Nation at Kitigan Zibi Anishinabeg First Nation, which would be followed by a site visit to CNL in May or June 2017
January 20, 2017	Telephone call from CNL to AANTC	■ Nicole LeBlanc, CNL ■ Norm Odjick, AANTC	Follow up phone call from CNL to AANTC where Norm indicated AANTC would like a joint meeting with CNSC and CNL in Maniwake
January 20, 2017	Email from CNL to Karry Sandy McKenzie, Williams Treaties First Nations, Process Coordinator	■ Phil Shantz, Arcadis on behalf of CNL ■ Karry Sandy McKenzie	Email in response to Chippewas of Rama First Nation indicating they had forwarded project information to Karry Sandy-McKenzie, Process Coordinator for the Williams Treaties First Nation
February 2, 2017	Telephone call from CNL to AANTC	■ Nicole LeBlanc, CNL ■ Norm Odjick, AANTC	Telephone call to confirm that the AANTC would like a separate presentation than CNL's presentation to the Kitigan Zibi Anishinabeg First Nation. However, Norm indicated that the AANTC would like a site visit to CNL with the Kitigan Zibi Anishinabeg First Nation

Table 4.3.2-2: Aboriginal Engagement Activities to Date

Date	Event/Activity	Attendance/Correspondence	Notes/Supporting Documentation
February 9, 2017	Letter to Curve Lake First Nation from CNL enclosing requested information	■ Melissa Dokis, Curve Lake First Nation ■ Pat Quinn, CNL	See Appendix 4.0-29 for the letter from CNL to Curve Lake, which encloses requested archaeological information on the NPD Closure Project, the Stage 1 Archeological Assessment; see Appendix 4.0-1 for posters sent to Curve Lake.
February 13, 2017	Letter to be sent to Algonquin of Ontario enclosing requested information on the NPD Closure Project	■ Janet Stavinga, AOO ■ Pat Quinn, CNL	n/a

4.3.2.2 *Summary of Feedback Received to Date*

As noted in Section 4.3.2.1, engagement activities with First Nation and Métis communities in support of the project continue as the environmental assessment and project planning activities progress. To date, communities have identified an interest in biodiversity and cultural heritage studies. CNL has:

- shared copies of documents related to biodiversity and archaeology produced in support of the NSDF Project with communities where they have identified an interest;
- shared informational posters with all communities; and,
- shared updated project information at periodic intervals.

In addition, the archaeological assessment field studies included the participation of First Nations community members.

4.3.3 Future Engagement Activities Planned

Engagement with the public and First Nation and Metis communities is ongoing and will continue throughout the life of the NSDF Project. CNL has identified additional engagement activities that are planned to take place after the submission of the EIS to the CNSC in March 2017. These additional activities are described below.

4.3.3.1 Ongoing Meetings with First Nations and Métis Communities

CNL will continue to engage with interested First Nation and Métis communities. Planned engagement activities include continued updates, sharing of information related to environmental assessment activities and findings. Future meetings are planned for Spring 2017.

4.3.3.2 Web Content Updates

The NSDF Project website, described in Section 4.3.1.1.8, will continue to be updated as the environmental assessment and planning for the NSDF Project continues. The final EIS will posted on the website, along with key technical supporting studies.

4.3.3.3 Webinars/Webcasts

Consideration is being given to expand CNL's reach and increase the accessibility of the stakeholder engagement through web casts/webinars with focused topics such as:

- biodiversity; and,
- cultural resources management at CNL with a focus on the NSDF Project.

It is planned that each webinar will be recorded through Google Hangouts on air and then posted to YouTube and www.cnl.ca/nsdf for future viewing by the public. The webinars will be interactive and moderated, where registered participants will have the opportunity to ask questions and comments will be recorded.

4.3.3.4 Technical Meeting

As discussed in Section 4.3.1.1.6, CNL held a Technical Meeting to provide interested parties, including those who have asked detailed questions and made comments at past meetings, with more in-depth information and a more substantial opportunity to question subject matter experts on the NSDF Project. CNL will conduct future Technical Meetings upon request of stakeholders.

This page intentionally left blank

5.0 ENVIRONMENTAL EFFECTS

5.1 Environmental Assessment Approach

The environmental assessment process is an important tool that is used to integrate environmental and social factors into project planning and decision-making. The goal of the environmental assessment process is:

- to promote sustainable development;
- to engage First Nations and Métis communities, the public and government agencies; and,
- to identify appropriate mitigation to reduce the overall biophysical, economic, social, heritage and health effects of the Near Surface Disposal Facility (NSDF) Project.

This section describes the scope and the environmental assessment approach implemented for the NSDF Project. The environmental assessment approach applied to disciplines (e.g., atmospheric environment, hydrogeology, terrestrial biodiversity, human health and socio-economic environment) includes the following main steps (where applicable), with further detail on each step provided in following subsections:

- define the scope of the assessment including input received from regulatory agencies and engagement activities;
- identify the Valued Components (VCs) for each discipline upon which the assessment will focus and the associated measurement indicators and assessment endpoints for VCs;
- define spatial and temporal boundaries, and assessment cases used to evaluate effects;
- describe existing conditions, including the cumulative effects of previous and existing developments for each VC;
- conduct a pathway analysis to identify Project components or activities with a potential to create a residual effect and describe the mitigation developed for removing pathways or limiting effects;
- conduct an assessment for each VC to predict residual effects from the NSDF Project;
- conduct an assessment for each VC to predict the cumulative effects of previous and existing projects and activities, the NSDF Project and potential future projects that have been proposed, but not yet approved (if applicable);
- evaluate and describe the level of certainty that can be placed on predicted residual effects;
- determine the significance of cumulative effects from the NSDF Project and potential future projects that have been proposed, but not yet approved (if applicable); and,
- identify monitoring and follow-up programs to address uncertainty.

Generally, elements of the approach can be consistently applied to all disciplines, with some modifications to disciplines, where appropriate. For example, the definition of a VC can be applied to all disciplines and there is consistency in the approach to determining the spatial and temporal boundaries for the effects analysis. Similarly, the approaches for identifying interactions that link the NSDF Project to potential effects on VCs are consistent.

In contrast, the methods for analyzing, classifying (e.g., magnitude and duration) and predicting environmental significance of residual effects can differ between discipline components. For example, human effects from a specific project are difficult to isolate from the ongoing processes of interdependent social, cultural and economic change. Evolving social trends, government policy and programming decisions, and individual choice all have effects that will be concurrent with potential Project effects. Biophysical disciplines (e.g., hydrogeology, aquatic environment and terrestrial environment) are influenced simultaneously by natural and human related factors. However, for many biophysical disciplines, Project-specific effects can be quantified (e.g., incremental changes to ground and surface water quality, air quality, and fish and wildlife habitat). Because the socio-economic status of different communities, subpopulations and individuals may vary, a socio-economic effect may have positive aspects and negative aspects. An effect on a biophysical discipline is typically constrained to being negative or positive.

Each of the steps identified above are described in the following sections; details specific to each discipline are provided in their respective sections of the Environmental Impact Statement (EIS).

5.1.1 Scope of the Assessment

As described in Section 1.4, the Generic EIS Guidelines developed by the Canadian Nuclear Safety Commission (CNSC 2016a) provides an outline of the information to be included in the EIS, along with a high-level description of the methods to be implemented for the environmental assessment.

The scope of the environmental assessment, where applicable, incorporates input received from regulatory agencies, First Nation and Métis peoples, and the public (Section 4.0), and advice provided in guidance documents relevant to environmental assessment practice (Section 1.4).

Input from engagement for the NSDF Project is used to identify the key issues that were raised during the engagement process (Section 4.0). Issues identified during community information sessions and considered in the development of the EIS are summarized in Appendix 4.1. Comments received, the responses prepared, and the degree to which these comments are considered resolved are also presented in Appendix 4.1. These issues and the response to these issues are presented in the ‘Scope of the Assessment’ heading within each discipline section, and helped to guide the scope and development of the assessment for each discipline.

5.1.2 Valued Components

Valued components refer to environmental features that may be affected by a project and that have been identified to be of concern by the proponent, scientists, government agencies, Aboriginal peoples, or the public (Canadian Environmental Assessment Agency [the Agency] 2014). Because this assessment is for a designated project, as described in the *Canadian Environmental Assessment Act, 2012* (CEAA 2012), and is regulated by the CNSC, VC selection considered guidance from Appendix A of the CNSC's REGDOC-2.9.1 Environmental Protection: Environmental Policy, Assessments and Protection Measures (CNSC 2016b). The selection of appropriate VCs allows the assessment to be focused on those aspects of the natural and human environment that are of greatest importance to society and species conservation.

The list of VCs selected for the NSDF Project considered a number of factors, including:

- presence, abundance and distribution within or relevance to the area associated with the NSDF Project;
- potential for interaction with the NSDF Project and sensitivity to effects;
- species conservation status or concern (e.g., rarity, sensitivity and uniqueness);
- ecological and socio-economic value to communities, government agencies and the public;
- traditional, cultural and heritage importance to First Nation and Métis peoples; and,
- experience with similar projects, including the EIS completed in 2010 for the National Research Universal Reactor Long-Term Management Project at the Chalk River Laboratories (CRL) property (AECL 2010).

Valued components were selected with due consideration of the results of baseline studies and subsequent consultation with a focus on criteria used to evaluate the potential significance of residual effects. The rationale for discipline-specific VC selection is described in Sections 5.2 to 5.10, under the 'Valued Components' subheading. The final list of VCs and rationale for inclusion in the effects assessment for the NSDF Project is provided in Table 5.1.2-1.

Table 5.1.2-1: Valued Components Selected for the Effects Assessment

Discipline	Valued Component	Rationale for Selection
Atmospheric Environment	Air Quality	■ Air quality is selected as a VC as emissions from the NSDF Project activities have the potential to alter the existing air quality regime. ■ Changes in air quality can affect human health, aquatic and terrestrial biodiversity.
	Climate Change	■ This valued component, assessed through incremental changes in emissions of a group of gases, considers the potential of the Project to contribute to climate change.
Geological and Hydrogeological Environment	Geology*	■ Characteristics of geology, such as soil quality and quantity, bedrock and geomorphology, are important components that interact with other VCs (e.g., hydrogeology, hydrology and surface water quality) and if changed by NSDF Project activities could affect terrestrial and aquatic biodiversity.
	Groundwater quantity* Groundwater quality*	■ Characteristics of hydrogeology, such as groundwater quantity and quality are important components that interact with other VCs (e.g., hydrology and surface water quality) and if changed by NSDF Project activities could affect terrestrial and aquatic biodiversity and human health.
Surface Water Environment	Hydrology*	■ The NSDF Project may affect existing availability of the spatial and temporal distribution of water quantity for aquatic and terrestrial biodiversity, which can subsequently affect land and resource use. ■ Societal values concerning changes in water quantity are an important consideration in understanding potential effects of the NSDF Project.
	Surface Water Quality*	■ Water quality to support aquatic and human health is defined by the concentration of various constituents, such as major ions (e.g., chloride, potassium), nutrients (e.g., nitrogen, phosphorus), metals that occur in dissolved or soluble form (e.g., aluminum and iron), and suspended matter (comprising inorganic or organic material). ■ Changes in the quality of water can affect aquatic and terrestrial biodiversity and the use of water as a drinking water source for people or for recreational purposes. ■ Societal values concerning changes in water quality are an important consideration in understanding potential effects of the NSDF Project.
Aquatic Environment	Fish	■ Up to 15 species have been documented within the Perch Lake watershed, some of which may use habitat in the Ottawa River at the mouth of Perch Creek. ■ Species in potentially affected waters are part of a commercial, recreational, or Aboriginal (CRA) fishery (DFO 2013), for example, Northern Pike (*Esox lucius*), Brown Bullhead (*Ameiurus nebulosus*) and supporting forage fish species. ■ Societal values concerning changes in local fisheries species are an important consideration in understanding potential effects of the NSDF Project.
	Fish Habitat	■ Wetlands, lakes, streams and rivers provide a diversity of functions for life history stages of CRA fish species, and forage fish that support CRA species. ■ The NSDF Project may affect existing availability of the spatial and temporal distribution of habitat, which can subsequently affect land and resource use.

Table 5.1.2-1: Valued Components Selected for the Effects Assessment

Discipline	Valued Component	Rationale for Selection
Terrestrial Environment	Vegetation Communities (including wetlands)	■ Broadly captures effects on terrestrial biodiversity. ■ NSDF Project is associated with footprint effects that will remove vegetation and result in physical losses of some vegetation communities (and related wildlife habitat).
	Migratory Birds	■ Migratory birds and their nests are protected under the federal *Migratory Bird Convention Act, 1994*. ■ There are numerous migratory bird species that breed, nest, and take up year-round residence in the vicinity of the NSDF Project. There is the potential for migratory birds to be indirectly and directly affected by the Project through disturbance, habitat loss, and mortality (i.e., vehicle strike on roads or loss of eggs in nests during tree clearing). ■ Comment on the Project Description received by a member of the public specifically requested assessment of this VC.
	Canada Warbler	■ Canada warbler (*Cardellina canadensis*) is federally listed as Threatened under SARA and listed under the MBCA. It has legal individual and habitat protection provisions under SARA and individual and nest protection under MBCA. ■ The RSA (CRL property) is federally-owned; therefore, this species is afforded protection of critical habitat because it is listed as Threatened on Schedule 1 of SARA. Critical habitat has not yet been defined for this species in the federal recovery strategy. ■ There is the potential for Canada Warbler to be indirectly and directly affected by the NSDF Project through disturbance, habitat loss, and mortality (i.e., vehicle strike on roads or loss of eggs in nests during tree clearing). ■ Avian species VC recorded within the Local Study Area (LSA) that represents a guild of early successional habitat specialists requiring coniferous, deciduous, moist mixed forest and regenerating habitats.
	Eastern Whip-poor-will	■ Eastern whip-poor-will (*Antrostomus vociferus*) is federally listed as Threatened under SARA and listed under the MBCA. It has legal individual and habitat protection provisions under SARA and individual and nest protection under MBCA. ■ The RSA (CRL property) is federally-owned; therefore, this species is afforded protection of critical habitat because it is listed as Threatened on Schedule 1 of SARA. Critical habitat has been partially defined for this species in the federal recovery strategy. ■ There is the potential for eastern whip-poor-will to be indirectly and directly affected by the NSDF Project through disturbance, habitat loss, and mortality (i.e., vehicle strike on roads or loss of eggs in nests during tree clearing). ■ Keystone avian species VC recorded within the LSA that represents a guild of aerial insectivores requiring open forest/edge habitat in drier deciduous and coniferous habitats.

Table 5.1.2-1: Valued Components Selected for the Effects Assessment

Discipline	Valued Component	Rationale for Selection
Terrestrial Environment	Golden-winged warbler	■ Golden-winged warbler (*Vermivora chrysoptera*) is federally listed as Threatened under SARA and listed under the MBCA. It has legal individual and habitat protection provisions under SARA and individual and nest protection under MBCA. ■ The RSA (CRL property) is federally-owned; therefore, this species is afforded protection of critical habitat because it is listed as Threatened on Schedule 1 of SARA. Critical habitat has been partially defined for this species in the federal recovery strategy. ■ There is the potential for golden-winged warbler to be indirectly and directly affected by the NSDF Project through disturbance, habitat loss, and mortality (i.e., vehicle strike on roads or loss of eggs in nests during tree clearing). ■ Keystone avian species VC recorded within the LSA that represents a guild of edge habitat specialists.
	Bats ■ Little brown myotis ■ Northern myotis ■ Tri-colored bat	■ Little brown myotis (*Myotis lucifugus*), northern myotis (*M. septentrionalis*), and tri-colored bat (*Perimyotis subflavus*) have observation records within the LSA. All three bat species are federally listed as Endangered and have legal individual protection provisions under the federal *Species at Risk Act* (SARA). ■ The RSA (CRL property) is federally-owned; therefore, these bat species are afforded protection of critical habitat because they are listed as Endangered on Schedule 1 of SARA. Critical habitat has only partially been defined for hibernacula, as the largest threat to these species is associated with that habitat; however, hibernacula have not been found in the study areas and are unlikely to occur in the SSA. Maternity roosts are likely present, and have the potential to be indirectly and directly affected by the NSDF Project through disturbance, habitat loss, and mortality (i.e., loss of roosting bats during tree clearing). ■ There is the potential for bats to be indirectly and directly affected by the NSDF Project through disturbance, habitat loss (loss of roost trees), and mortality (i.e., loss of pre-volant juveniles in maternity roosts during tree clearing). ■ Represents small mammal species recorded in the LSA that rely on wildlife trees (i.e., snags) for part of their life history (maternity roosting, diurnal roosting, and evening roosting).
	Blanding's turtle	■ The Great Lakes/St. Lawrence population of Blanding's turtle (*Emydoidea blandingii*) is federally listed as Threatened and has legal individual and habitat protection provisions under SARA. ■ The RSA (CRL property) is federally-owned; therefore, this species is afforded protection of critical habitat because it is listed as Threatened on Schedule 1 of SARA. Proposed critical habitat has been identified within the CNL property based on the definition in the proposed Recovery Strategy (Environment Canada 2016a). ■ There is the potential for Blanding's Turtle to be indirectly and directly affected by the NSDF Project through disturbance, habitat loss, and mortality (i.e., vehicle strike on roads). ■ Represents reptile species that use a variety of wetland habitats for hibernation, mating, foraging, thermoregulation, staging prior to nesting and for movement. They use upland, relatively open areas with suitable substrate for nesting, overland migration, thermoregulation and foraging. Blanding's turtles display fidelity to their overwintering sites and nesting sites (i.e. use the same habitat year after year).

Table 5.1.2-1: Valued Components Selected for the Effects Assessment

Discipline	Valued Component	Rationale for Selection
Ambient Radioactivity and Ecological Health	A list of proposed VCs was developed from those that are documented to occur in the vicinity of the NSDF site, have potential for exposure, play a key role in the food web, and represent a variety of habits and trophic levels. In order to determine the potential effect of radiological emissions on the environment, a smaller group of indicator species was chosen to represent VCs selected for assessment.	
	Earthworm	■ Indicator species for changes in soil quality.
	Crustaceans	■ Indicator species for changes in sediment quality.
	Bluntnose minnow	■ Indicator species for small pelagic forage (omnivores) fish species.
	Black Bullhead	■ Indicator species for small benthivorous fish species.
	Northern Pike	■ Indicator species for large benthivorous fish species.
	Reed	■ Indicator species for aquatic macrophytes.
	Red Maple	■ Indicator species for terrestrial vegetation communities.
	Monarch Butterfly	■ Indicator species for pollinator species.
	Little brown Myotis	■ Indicator species for small insectivore species.
	Meadow Vole	■ Indicator species for small herbivore mammals.
	White-tailed deer	■ Indicator species for large herbivore mammals.
	Short-tailed Shrew	■ Indicator species for small omnivorous mammals.
	Black Bear	■ Indicator species for large omnivorous mammals.
	Eastern Wolf	■ Indicator species for large carnivorous mammals.
	Snapping Turtle	■ Indicator species for semi-terrestrial reptile species.
	Common Watersnake	■ Indicator species for semi-terrestrial reptile species.
	Eastern Milksnake	■ Indicator species for terrestrial reptile species.
	Green Frog	■ Indicator species for amphibian species.
	Canada Warbler	■ Indicator species for small insectivore bird species.
	Eastern Whip-poor-will	■ Indicator species for large insectivore bird species.
	Purple Finch	■ Indicator species for small omnivore bird species.
	Ruffed Grouse	■ Indicator species for large omnivore bird species.

Table 5.1.2-1: Valued Components Selected for the Effects Assessment

Discipline	Valued Component	Rationale for Selection
Ambient Radioactivity and Ecological Health	Belted Kingfisher	■ Indicator species for small carnivore bird species.
	Bald Eagle	■ Indicator species for large carnivore bird species.
	Mallard	■ Indicator species for small semi-aquatic bird species.
	Great Blue Heron	■ Indicator species for large semi-aquatic bird species.
Socio-economic Environment	Labour Market	■ Local workforce and communities are interested in long-term employment opportunities that will be generated through the NSDF Project. ■ Income generation is perceived as a Project benefit by local workforce, businesses, and communities.
	Economic Development	■ The NSDF Project will contribute to local and regional economies, through direct procurement, as well as indirect investment in other business activities.
	Government Finances	■ The NSDF Project will generate incremental tax revenues for government.
	Housing and Accommodations	■ Potential in-migration of workers (and families) for the NSDF Project could increase the demand for permanent housing or temporary accommodations.
	Services and Infrastructure	■ Potential in-migration of workers (and families) for the NSDF Project could increase the demand for community services (i.e., schools, community health, protection and emergency services) and community infrastructure (i.e., water supply and traffic).
	Quality of Life	■ Project activities (i.e., changes in air quality, ambient noise, increases in traffic volume, and visual disturbances) could affect worker and local public quality of life.
	Public Safety	■ Public safety is a concern near the NSDF Project. Hazards include transportation of construction equipment and construction materials to site.
Land and Resource Use	Land Tenure and Other Registered Interests	■ Construction and operation must demonstrate compatibility with existing land use direction as expressed by responsible authorities based on a qualitative comparison of the NSDF Project with established land and resource designations in plans, policies and bylaws.
	Outdoor Recreation and Tourism	■ The NSDF Project has the potential to affect the access to outdoor tourism and recreational land and resource use opportunities associated with parks and protected areas, fishing, hunting, trapping and non-consumptive tourism and recreation. ■ The NSDF Project has the potential to affect the quality and quantity of outdoor tourism and recreation land use opportunities.
	Cultural and archaeological sites	■ Archaeological sites are an important aspect of First Nation and Métis communities cultural heritage. ■ Archaeological sites are the focus of the archaeology discipline as archaeological sites are identified and protected by the Ontario *Heritage Act*.

Table 5.1.2-1: Valued Components Selected for the Effects Assessment

Discipline	Valued Component	Rationale for Selection
Land and Resource Use (continued)	Traditional Land and Resources Use by First Nation and Métis Communities	■ Trapping, hunting, fishing, and gathering were traditional and modern dayland and resource use activities practiced by First Nation and Métis communities in the Ottawa Valley. These activities provide important links to cultural continuity and traditional way of life. ■ First Nation and Métis communities can place a high degree of value on specific sites of cultural, historical, spiritual, social or ecological significance. These sites may have broader cultural significance related to the practice of formal or informal ceremonies at or near these sites.
Human Health	Worker Health	■ Potential external and internal radionuclide exposure from NSDF Project activities.
	Public Health ■ Residential ■ Seasonal ■ Beef Farmer ■ Dairy Farmer ■ Industrial Worker	■ Potential Critical Groups were selected based on lifestyle and proximity to the CRL site. The critical groups selected are those that are likely to receive the highest radiation doses as a result of CRL operations.

Note: Valued components denoted with an '*' indicate a valued component that does not have an assessment endpoint.

Assessment endpoints are qualitative expressions used to assess the significance of residual effects on VCs and represent the key properties of the VC that should be protected for future human generations (i.e., incorporates sustainability). For example, self-sustaining and ecologically effective fish and wildlife populations, continued land use opportunities and protection of archaeological resources may be assessment endpoints for fish and wildlife, land use and tenure and archaeological resources, respectively. Assessment endpoints are typically not quantifiable and require the identification of one or more measurement indicators that can be directly linked to the assessment endpoint.

Measurement indicators represent properties of the environment and VCs that, when changed, could result in or contribute to an effect on assessment endpoints. Measurement indicators may be quantitative (e.g., concentrations of metals in surface water) or qualitative (e.g., movement and behaviour of wildlife from disturbance to habitat). Measurement indicators also provide the primary factors for discussing the uncertainty of effects on VCs and, subsequently, are key variables for study in potential follow-up and monitoring programs.

The significance of effects from the NSDF Project on VCs is evaluated by linking changes in measurement indicators to effects on the assessment endpoints. For example, changes in habitat quantity and quality (measurement indicators) are used to assess the significance of residual effects from the NSDF Project on the ability of a wildlife population to remain self-sustaining and ecologically effective (an assessment endpoint).

All VCs have measurement indicators, but not every VC has an assessment endpoint. For example, VCs such as geology, hydrogeology and surface water are considered as measurement indicators for other VCs, and do not have an assessment endpoint (i.e., may be referred to as pathway or intermediate components). Intermediate components are considered to be important aspects of the natural and human environment, and are evaluated in the EIS to determine how they may influence assessment endpoints. The evaluation includes an analysis of changes in measurement indicators for the intermediate components. The results of the analysis are provided to other disciplines (e.g., aquatic and terrestrial environment, and human health) for inclusion in their residual effects analysis.

Valued components with no assessment endpoint are still analyzed for Project-specific and cumulative (if applicable) changes in measurement indicators. The changes are characterized in terms of magnitude, duration and geographic extent, but are not classified using rankings for effects criteria. For example, the magnitude of change in hydrological flows may be described as the relative change from baseline; however, this change would not be classified (or ranked) as low, moderate or high. This ranking would be reserved for the classification of residual effects and determination of significance for those VCs with assessment endpoints.

In summary, the same systematic and rigorous approach is applied to VCs with and without assessment endpoints, except that effects on VCs without explicit assessment endpoints are not classified using effects criteria nor evaluated for significance. The environmental assessment approach for VCs with assessment endpoints is illustrated on Figure 5.1.2-1, and the approach for VCs with no assessment endpoints is illustrated on Figure 5.1.2-2. The assessment approach is described further in Sections 5.1.3 to 5.1.9.

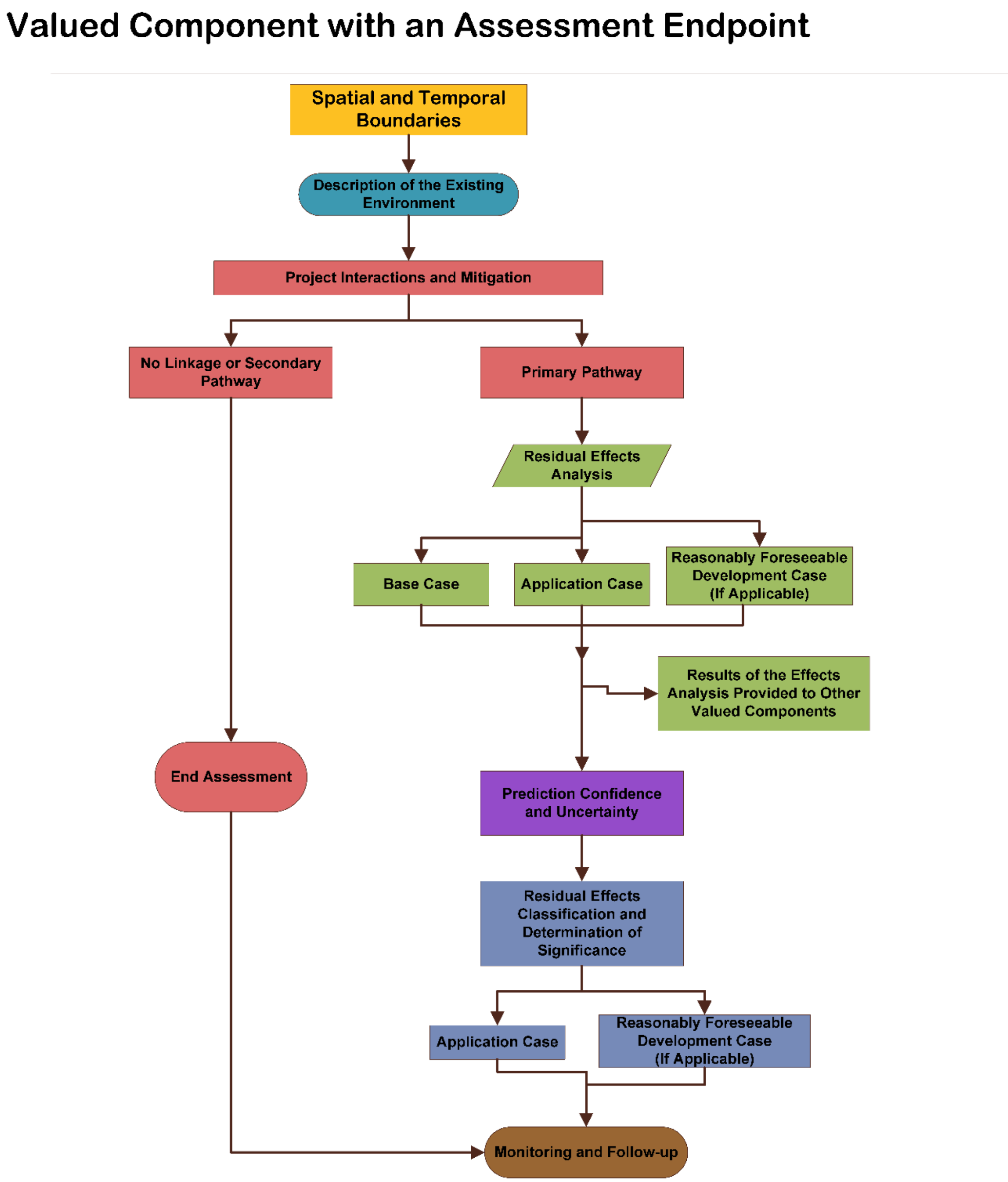


Figure 5.1.2-1: Environmental Assessment Approach for Valued Components with an Assessment Endpoint

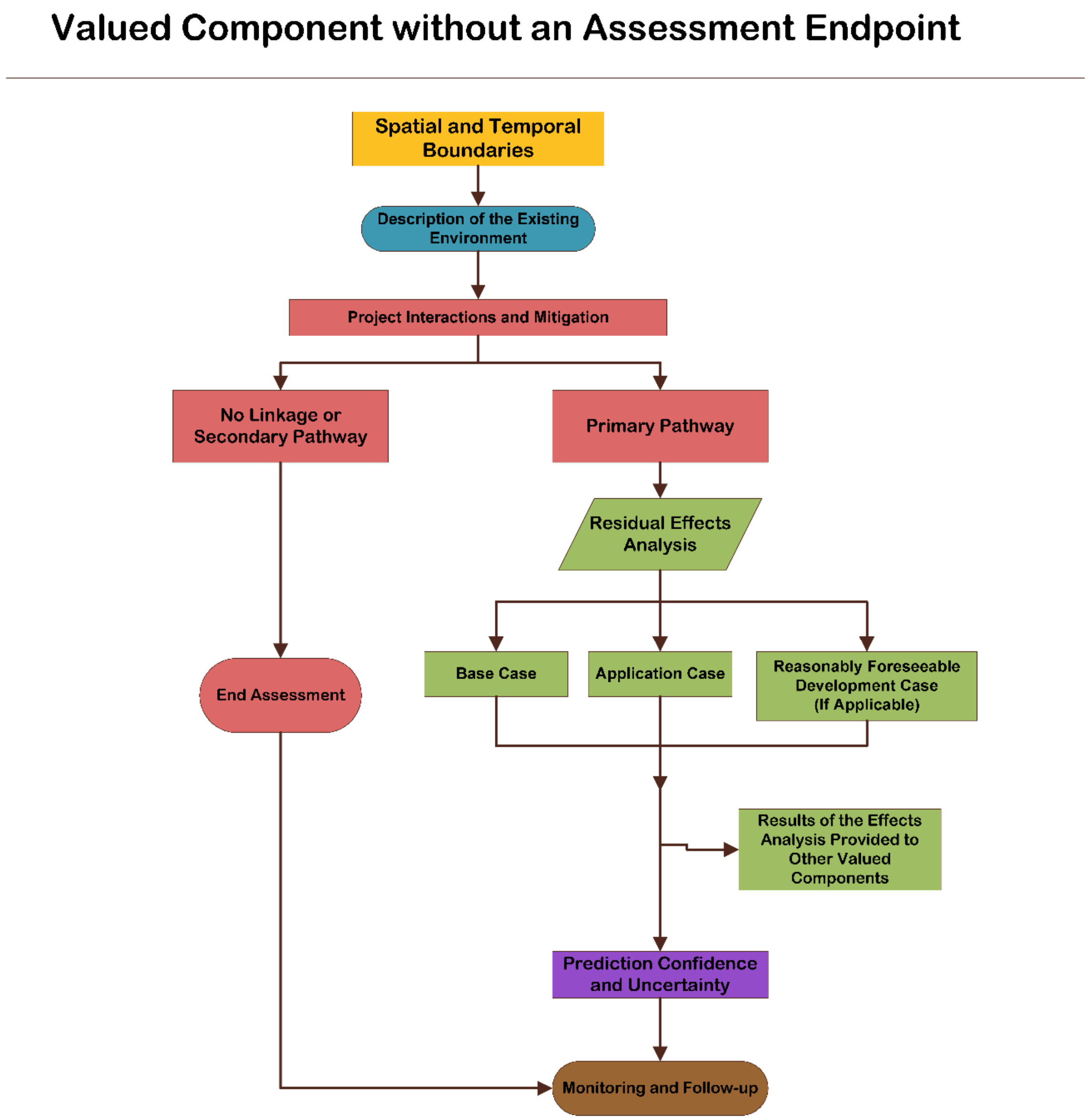


Figure 5.1.2-2: Environmental Assessment Approach for Valued Components without an Assessment Endpoint

5.1.3 Assessment Boundaries

Assessment boundaries define the geographic and temporal scope or limits of the analysis of effects from the NSDF Project on the environment. These boundaries encompass the areas within (spatial boundaries) and times during (temporal boundaries) which the NSDF Project, and in combination with previous, existing and reasonably foreseeable developments, is expected to interact with the VCs.

5.1.3.1 Spatial Boundaries

Defining the geographic extent of the study areas for each discipline is a key element of the environmental assessment process. Spatial boundaries are selected to be appropriate for each discipline (e.g., hydrogeology, surface water environment, terrestrial biodiversity and socio-economics), and associated VCs, using the following criteria:

- physical extent of the NSDF Project;
- physical extent of Project-related effects; and,
- physical extent of key environmental systems (e.g., watershed boundary of potentially affected streams).

Individuals, populations and communities function within the environment at different spatial and temporal scales (Wiens 1989). In addition, the response of physical, chemical and biological processes to changes in the environment can occur across several spatial scales at the same time (Holling 1992; Levin 1992). This environmental assessment has adopted a multi-scale approach for describing baseline conditions (existing environment) and predicting effects from the NSDF Project on VCs because the responses of physical, biological, cultural and economic properties to natural and human-induced disturbance will be unique and will occur across different scales.

For this EIS, data collected at the NSDF Project Site and within the CRL property were used to provide measures of baseline environmental conditions and predict the direct and indirect changes from the NSDF Project on VCs (e.g., changes to terrestrial habitat from the physical footprint). Data collected at larger scales (i.e., outside of the CRL property) were used to measure broader-scale baseline environmental conditions, and provide regional context for the maximum predicted geographic extent of combined direct and indirect effects from the NSDF Project on VCs (e.g., changes to downstream water quality, or changes to regional employment and incomes). Cumulative effects from the NSDF Project in combination with previous, existing and reasonably foreseeable developments are assessed at the regional spatial scale.

As indicated in the CNSC Generic EIS Guidelines (2016a), the following spatial scales will be considered by each discipline.

- **Site Study Area (SSA):** the SSA is the NSDF Project footprint (i.e., where Project activities would be undertaken including the NSDF Project's proposed facilities, buildings and infrastructure).
- **Local Study Area (LSA):** the LSA is selected in consideration of the Project footprint, and the spatial extent of potential direct effects of the Project on the VCs. The LSA was selected to represent an area that is likely to be directly affected by the Project, helping to identify Project-specific (rather than cumulative effects of the project in combination with other projects in the region).

- **Regional Study Area (RSA):** the RSA is defined as the area within which the maximum geographical extent of potential indirect effects of the Project may interact with the effects of other existing or reasonable foreseeable projects.

The spatial boundary for the study areas considered by each discipline and the rationale for their selection are identified in Sections 5.2 through 5.10 under the 'Assessment Boundaries' heading. The study areas are illustrated on maps of appropriate scale which are also included in Sections 5.2 through 5.10 under the 'Assessment Boundaries' heading.

5.1.3.2 Temporal Boundaries

Temporal boundaries (i.e., project phases) establish the timeframe during which NSDF Project effects are assessed. The temporal boundary represents the timeframe during which project activities are actively occurring, and does include the duration of predicted residual effects. The duration of an effect is defined as the amount of time between the start and end of a Project activity or stressor (which is related to the project phases) plus the time required for the residual effect to be reversed. In some cases, a residual effect may be irreversible within the temporal boundaries of the Project (e.g., residual effect lasts for thousands of years). The following phases were identified for the NSDF Project.

- **Construction Phase**: includes site preparation and all activities associated with the construction of the NSDF. This phase includes activities such as installing the necessary supporting and/or ancillary facilities and NSDF infrastructure to facilitate NSDF operations, inactive commissioning and systems testing, and transportation of construction materials. Construction activities are expected take place from 2018 to 2020.

- **Operations Phase**: includes all activities associated with the landfilling of waste receipt, waste placement, water management, wastewater treatment plant operations, vehicle movements into and from the NSDF Project site, and maintenance activities. Operations activities are expected to last approximately 50 years (i.e., 2020 to 2070).

- **Closure Phase:** includes activities necessary to complete the installation of the final cover and implementation of long-term monitoring. Closure activities are expected to start in 2070 and continue through to 2100, after which the NSDF Project will transfer into the post-closure phase.

- **Post-closure Phase:** has two discrete periods: Institutional Control and post-Institutional Control. The Institutional Control period includes implementation of both active and passive control throughout 2100 to 2400 (i.e., 300 years). During Institutional Control, groundwater monitoring and groundwater quality management will continue to demonstrate compliance with the safety case assumptions. Post-institutional Control occurs after year 2400 and continues indefinitely.

Baseline studies associated with each VC identify temporal variation (e.g., annual or seasonal changes in water flow or habitat use, or trends over time in populations and employment) and other biophysical constraints relevant to the assessment of the NSDF Project. The final selection of temporal boundaries is discipline-specific and include consideration of the phases described above. For some VCs, residual effects are assessed for all phases of the NSDF Project, but not necessarily for each specific phase. For example, effects on wildlife begin during the construction stage with the removal and alteration of habitat (i.e., results in direct and indirect changes) and continue through the operation phase and for a period after the closure phase until reversed, unless determined to be irreversible or permanent. Therefore, effects on wildlife are analyzed and predicted from

construction through closure stages, which generates the maximum potential spatial and temporal extent of effects, and provides confident and ecologically relevant effects predictions.

Alternately, for some VCs, the assessment was completed for those phases of the NSDF Project where predicted effects would be expected to peak (e.g., most air quality effects from emissions occur during construction) or at several key points in time. These points in time may include several periods within or among Project phases. Examples include comparing the maximum extent of disturbance to vegetation during operations to the amount that will be reclaimed at closure, or evaluating surface water quality predictions at specific times that represent key milestones throughout the life of the NSDF Project. For other VCs, the assessment of effects may continue beyond the reclamation and closure stage.

Similarly, the temporal boundaries identified for cumulative effects assessments are specific to the VCs being assessed. Temporal boundaries include the duration of residual effects from previous and existing developments that overlap with residual effects of the NSDF Project, and the period during which the residual effects from reasonably foreseeable developments will overlap with residual effects from the NSDF Project. The temporal boundaries considered by each discipline are identified in Sections 5.2 through 5.10 under the ‘Assessment Boundaries’ heading.

5.1.3.3 Assessment Cases

This section will provide a brief description the assessment cases considered in the EIS. The assessment cases are discipline-specific and include the following.

- **Base Case –** This scenario represents existing conditions and characterizes combined effects from previous and existing developments and activities. The Base Case reflects the effects of existing disturbances, such as forestry, transportation, agricultural, mining, and residential and recreational development. Current effects from the existing CRL facilities and operations, for example, are considered part of the Base Case.
- **Application Case –** This scenario represents predictions of the effects of the Base Case combined with the effects that may result from the NSDF Project.
- **Reasonably Foreseeable Developments (RFD) Case –** this scenario represents predictions of the cumulative effects of the Application Case, which includes the Base Case, plus projects that are currently under application review or that have officially entered a regulatory application process, and are therefore, considered reasonably foreseeable. In addition, effects from the future decommissioning and reclamation activities to be completed at the CRL site are also considered as part of the RFD Case.

5.1.4 Description of the Environment

To provide a basis for evaluating potential changes of the NSDF Project, each discipline assessment includes a description of the baseline conditions in the ‘Description of the Environment’ subsection. The baseline studies are completed to develop an understanding of the existing physical, biological and social conditions that may be influenced by the NSDF Project and are used to prepare a Base Case. The Base Case includes the cumulative effects from all previous and existing developments in the study area of a VC. Existing environment or baseline conditions represent the historical and current environmental selection pressures that have shaped the observed patterns in VCs. Environmental selection pressures include natural (e.g., weather, predation and competition) and human-related factors (e.g., mineral development, forestry, traditional and sport hunting and fishing).

Existing conditions are described recognizing that baseline conditions typically fluctuate within a range of variation through time and space depending on which selection pressures are currently driving changes to the VC and system. The fluctuations are generated by variation in natural factors (natural variation) and variation associated with human influences. Relative to ecological time and space, baseline conditions are in a constant state of change due to the pushing and pulling of environmental selection pressures. The Base Case thus describes the existing environment without the implementation of the NSDF Project, and is used to provide an understanding of the physical, biological and social conditions that may be influenced by the NSDF Project.

Information sources included published and unpublished material, and baseline and other monitoring data collected by CNL. This information was reviewed and analyzed to determine the presence of data gaps. Baseline field studies were then planned and carried out to fill the identified gaps. Relevant existing data from previous studies and the results of the recent baseline field programs are presented in the discipline-specific sections. Traditional knowledge, including Aboriginal traditional knowledge, if available, was included in the baseline information.

The methods and results of the data collection described above that are directly relevant to the assessment of Project effects are summarized in the 'Description of the Environment' sub-sections in Sections 5.2 through 5.10.

5.1.5 Project Interactions and Mitigation

Interactions (linkages) between Project components or activities and the corresponding potential changes to measurement indicators are identified by a pathway analysis that is then used to focus the residual effects assessment for the VCs. The first part of the analysis is to identify all pathways by which a Project component or activity could cause a potential effect. Each pathway is initially considered to have a linkage to potential effects on VCs. For an effect to occur there has to be a Project component or activity that results in a detectable change to the measurement indicators and a correspondent effect on a VC.

Project Activity → Effects Pathway that Results in a Detectable Change in a Measurement Indicator or Intermediate Component → Effect on the Assessment Endpoint of a VC

The development of the potential pathways is followed by the screening of potential pathways to determine if mitigation is required; and if so, the development of environmental design features and mitigation that can be incorporated into the NSDF Project to remove a pathway (i.e., eliminate the potential effect) or limit (i.e., mitigate) adverse effects on VCs. Environmental design features and mitigation include engineering design elements, environmental best practices, management policies and procedures, and spill response and emergency contingency plans. The description of environmental design features and mitigation will be specific to each discipline and the associated VCs. Any uncertainty associated with the effectiveness of proposed mitigation actions will be noted.

The purpose of the pathway analysis is to focus the residual effects analysis on linkages that require a more comprehensive assessment of effects on VCs, or those pathways that are likely to result in residual effects on a VC. Pathways are determined to have no linkage, a secondary (minor) linkage, or a primary linkage using scientific knowledge, logic, experience with similar developments, and the effectiveness of environmental design features. Each potential pathway is evaluated and described as follows:

- **No linkage** – analysis of the potential pathway reveals that there is no valid linkage between the NSDF Project and the VC, or the pathway is removed by environmental design features or mitigation so that the NSDF Project would not be expected to result in a measurable environmental change and would therefore have no residual effect on a VC relative to existing conditions or guideline values.
- **Secondary** – pathway could result in a measurable minor environmental change, but would have a negligible residual effect on a VC relative to existing conditions or guideline values, and is not expected to contribute to effects of other existing, approved, or RFDs to cause a significant effect.
- **Primary** – pathway is likely to result in an environmental change that could contribute to residual effects on a VC relative to existing conditions.

Pathways with no linkage to a VC, either because there was no linkage initially or because environmental design features or mitigation will remove the pathway, are not advanced for further assessment. Pathways that are assessed to be secondary and demonstrated to have a negligible residual effect on a VC through simple qualitative or semi-quantitative evaluation of the pathway are also not advanced for further assessment. In summary, pathways determined to have no linkage to a VC or those that are considered secondary are not expected to result in environmentally significant effects on the assessment endpoint of VCs, individually or cumulatively. Primary pathways require further effects analysis and classification to determine the environmental significance of the NSDF Project effects on VCs. A matrix table is included in Appendix 5.1-1 summarizing Project interactions for each VC that are determined to be no linkage, secondary, or primary, after consideration of environmental design features and mitigation.

5.1.6 Residual Effects Analysis

The residual effects analysis is based on the NSDF Project interactions that are determined to be primary in the pathway analysis. For primary pathways that require a residual effects analysis, the concept of assessment cases is applied to estimate the incremental and cumulative effects from the NSDF Project, as well as previous, existing and reasonably foreseeable developments. The residual effects analysis is completed for the Application Case and the RFD Case.

5.1.6.1 Application Case

This Application Case scenario represents predictions of the cumulative effects of the existing environment combined with the effects that may result from the NSDF Project. The residual effects analysis for the Application Case is based on residual Project-specific (incremental) effects that are evaluated to be primary in the pathway analysis. The environmental design features and mitigation identified in the NSDF Project Interactions and Mitigation section (Section 5.1.5) will be described in this section. Thus, the residual effects analysis will consider all primary pathways that will likely result in detectable changes in measurement indicators, and subsequent residual effects on VCs, after implementing environmental design features and mitigation. The Application Case

scenario represents effects predictions of the projects represented in the existing environment (Base Case) combined with the effects that may result from the NSDF Project.

The Application Case represents predictions of the cumulative effects of the developments in the Base Case combined with the effects from the NSDF Project. Where relevant, this case was used to identify the incremental changes from the NSDF Project that are predicted to occur between the Base Case and the Application Case. The residual effects analysis considers the proposed environmental design features and mitigation identified in the Project Interaction and Mitigation section (Section 5.1.5 Project Interactions and Mitigation).

The temporal boundary of the Application Case begins with the anticipated first year of construction of the NSDF Project, and continues until the predicted effects are reversed. For several VCs, the temporal extent of some effects likely will be greater than the lifespan of the NSDF Project because the effects will not be reversible until beyond closure. For other VCs, the effects may be determined to be irreversible within the temporal boundary of the Application Case. Such effects may be permanent or the duration of the effect may not be known, except that it is expected to be extremely lengthy (i.e., more than 100 years past closure).

Results of the effects analyses for the Application Case are used to describe the magnitude, duration and geographic extent of the predicted changes to measurement indicators and residual effects on VC assessment endpoints. Expected changes are expressed quantitatively or numerically, wherever possible. For example, the magnitude of the effect may be expressed in absolute or percentage values above or below baseline conditions or a guideline value. The duration, including reversibility, of the effect typically is described in years relative to the phases of development of the NSDF Project and the spatial extent of effects is typically expressed in area or distance from the NSDF Project. In addition, the direction, frequency, reversibility, probability and context of effects are described, where applicable. Rankings such as short term duration or moderate magnitude are not used in the effects analysis. These rankings are applied to the classification of effects and determination of significance, where definitions of these rankings are provided.

Effects on social, economic and cultural properties include positive and negative changes to employment, training and education, family income, traditional land use, family and community cohesion, and long-term social, cultural and economic sustainability. Some of these measurement indicators can be analyzed quantitatively (e.g., number of jobs created and estimated income levels). Other indicators such as community cohesion and traditional land use are more difficult to quantify, and involve information from public engagement, literature, examples from similar projects under similar conditions, and scientific knowledge and experience. The effects analysis considers the interactions among the unique and common attributes, challenges and opportunities related to social, cultural and economic measurement indicators.

5.1.6.2 Reasonably Foreseeable Development Case

The RFD Case scenario includes the Application Case plus additional reasonably foreseeable developments in the region that have not yet been approved. Developments and activities that are currently under application review, have officially entered a regulatory application process were considered reasonably foreseeable. This section describes the general methods used to predict whether the cumulative effects from the NSDF Project, in combination with existing, previous and reasonably foreseeable developments and activities are likely to result in environmental, social, economic, heritage and health effects, taking into account the mitigation actions proposed in the EIS.

The CEAA 2012 requires that each environmental assessment of a designated project take into account any cumulative environmental effects that are likely to result from the designated project in combination with the environmental effects of other physical activities that have been or will be carried out (The Agency 2015). Cumulative effects such as those that are likely from a reviewable project, combined with the effects from prior development, existing activities and reasonably foreseeable future developments that are sufficiently certain to proceed. Therefore, the RFD Case represents predictions made about the cumulative effects of the Application Case, which includes the Base Case, plus projects that are currently under application review or that have officially entered a regulatory application process, and are therefore, considered reasonably foreseeable.

The RFD Case includes the predicted duration of residual effects from the NSDF Project, plus other previous, existing and future developments and activities. Thus, the minimum temporal boundary for the Application Case and the RFD Case is the expected lifespan of the NSDF Project, which like the Base Case, includes a range of conditions over time. The difference between the Application Case and the RFD Case is that the Application Case considers the incremental effects from the NSDF Project in isolation of potential future land use activities.

The VCs requiring an analysis under the RFD Case are determined by understanding whether the residual effects from the NSDF Project and one or more additional developments (or activities) overlap or interact with the temporal or spatial distribution of the VC. Where potential cumulative effects from the RFD Case are identified for these VCs, these effects will be assessed using the same approach used for the NSDF Project-specific effects analysis (Section 5.1.6.1).

The analysis for the RFD Case is quantitative where possible and qualitative where necessary. The analysis is quantitative for those future projects that could be assigned a location, a physical footprint (i.e., known or hypothetical) on the landscape, and information about project emissions (e.g., to air and water). The analysis is qualitative for developments that did not have this information. For all RFDs, the EIS uses the most current information available for the location, size and type of activity associated with a project.

5.1.7 Prediction Confidence and Uncertainty

The purpose of an environmental assessment is to predict the future conditions of the biophysical and human environments as a result of a proposed project or development. Because the biophysical and human environment changes naturally and continually through time and across space, most assessments of effects embody some degree of uncertainty. The purpose of the uncertainty sections of the assessment is to identify the key sources of uncertainty, and to discuss how uncertainty is addressed to increase the level of confidence that effects will not be worse than predicted. Confidence in effects analyses can be related to many elements, including the following:

- adequacy of the baseline data for providing an understanding of the existing conditions and future changes unrelated to the NSDF Project (e.g., rate and extent of future developments, climate change or catastrophic events);
- model inputs (e.g., changes in chemical concentration in water over time and space);
- understanding of Project-related effects on complex ecosystems that contain interactions across different scales of time and space (e.g., how and why the NSDF Project will influence wildlife);
- limited knowledge and experience with the type of effect in the system;

- knowledge of the effectiveness of the environmental design features for reducing or removing effects (e.g., environmental performance of the base liner);
- uncertainties associated with the waste acceptance criteria, and exact location, physical footprint and activity level of the NSDF Project, as well as the timing, nature and rate of future developments in the RFD Case; and,
- uncertainties in the direction, magnitude and spatial extent of future fluctuations in ecological, cultural and socio-economic variables, independent of effects from the NSDF Project and other developments.

Uncertainty in these elements can decrease confidence in the prediction of environmental significance. Discipline studies use quantitative methods, such as sensitivity analyses, or qualitative discussion to assess prediction confidence to the extent reasonable. Assumptions for statistical tests, and details on models that were used as part of the assessment, are discussed within each discipline of study. Where possible, methods are used to reduce uncertainty and increase the level of confidence in effects predictions, as shown in the following examples.

- Using the results from several models and analyses to help reduce bias and increase precision in prediction.
- Using data from effects monitoring programs and literature as inputs for models rather than strictly hypothetical or theoretical values.

In addition, a conservative approach was implemented when information is limited so that effects are typically overestimated (e.g., defining the key input variables so that the result is a conservatively high effects prediction). Where appropriate, residual uncertainty is addressed by additional mitigation and in monitoring and follow-up programs. Each discipline of study includes a discussion of how uncertainty is addressed and provides a qualitative evaluation of the resulting level of confidence, which is included in the residual effects classification and determination of significance discussions.

5.1.8 Residual Effects Classification and Determination of Significance

5.1.8.1 Residual Effects Classification

The purpose of the residual effects classification is to describe the residual incremental and cumulative adverse effects from the NSDF Project and other developments on VCs using a common set of criteria. The classification criteria provide definitions that permit a clear, thorough and unambiguous classification of residual effects such that reviewers and readers can follow and apply the logic used in the assessment and reach the same classification for a given residual effect. The residual effects classification is then used to make significance determinations. The intent of the environmental assessment is to predict if the NSDF Project is likely to cause a significant adverse (i.e., negative) effect on the environment or to cause public concern.

The classification of residual adverse effects and the determination of significance are completed for those VCs that have assessment endpoints, and where residual adverse effects are predicted. The residual effects classification takes into consideration additional mitigation identified (if applicable) in the residual effects assessment. The results of the classification are used to determine the significance of predicted adverse effects.

Effects are classified using the following criteria, which follows the Environmental Assessment Guidelines provided by the CNSC (CNSC 2016a) and the Agency's *Technical Guidance: Assessing Cumulative Environmental Effects under the Canadian Environmental Assessment Act, 2012* (the Agency 2014). Specific definitions for the classification criteria have been developed for each VC or discipline of study.

Direction - Direction indicates whether the residual effect on a VC is negative (i.e., less favourable), positive (i.e., improvement) or neutral (i.e., no change). Neutral and positive changes are not assessed for significance.

Magnitude - Magnitude is a measure of the intensity of a residual effect, or the degree of change caused by the NSDF Project (and other developments, if applicable) relative to baseline conditions, guidelines or threshold values. Magnitude is typically classified into three scales: negligible to low, moderate and high. The scales of magnitude are specific to each VC or discipline of study, and incorporate the geographic extent and duration of residual effects in context of the properties of VC assessment endpoints. Where possible, magnitude is reported in absolute and in relative terms.

Geographic Extent - This criterion refers to the spatial extent of the effect, and is different from the spatial boundary (i.e., study area) for the residual effects analysis. The spatial boundary for the residual effects analysis represents the maximum area used for the assessment, and is related to the spatial distribution and movement of VCs. The geographic extent of residual effects can occur on multiple scales within the spatial boundary of the assessment. Geographic extent refers to the area affected, and is often categorized into three scales of local, regional and beyond regional.

Duration - Duration is defined as the amount of time (usually in years) from the beginning of a residual effect on when the residual effect to a VC is reversed and is expressed relative to Project phases. Duration has two components. It is the amount of time between the start and end of a Project activity or stressor (which is related to Project development phases), plus the time required for the residual effect to be reversed.

Reversibility - After removal of the NSDF Project activity or stressor, reversibility is the likelihood that the NSDF Project will no longer influence a VC in a future predicted period. Reversibility usually has only two alternatives: reversible or irreversible. The period is provided for reversibility (i.e., duration) if a residual effect is reversible. Permanent residual effects are considered irreversible.

Frequency - Frequency refers to how often a residual effect will occur and may be expressed as isolated, periodic or continuous. Frequency is explained more fully by identifying when the residual effect occurs (e.g., once at the beginning of the NSDF Project). If the frequency is periodic, then the length of time between occurrences and the seasonality of occurrences (if present) is discussed.

Likelihood - Likelihood is the probability of an effect occurring and is described in parallel with uncertainty. This criterion may be influenced by a variety of factors, such as the likelihood of disturbance occurring or the likelihood of mitigation being successful. Four classification categories are typically used: unlikely, possible, likely and highly likely.

The specific definitions applied to the above classification criteria for each VC or discipline of study are based on the ecological or socio-economic processes and properties of the VC or discipline of study. Although some professional judgement or experienced opinion is inevitable in determining the scales for effects predictions, the residual effects, to the extent possible, are classified using scientific principles, established guidelines, thresholds or target values, and supporting evidence.

5.1.8.2 Determination of Significance

The residual effects classification of primary pathways and the associated predicted changes in measurement indicators provide the foundation for determining the significance of incremental and cumulative effects from the NSDF Project and other existing, approved, and reasonably foreseeable developments on VC assessment endpoints. For some VCs, there may be no RFD Case and the assessment is limited to determining the significance of residual effects from the NSDF Project and previous and existing developments (i.e., Application Case). For those VCs that may be influenced by forecasted future developments, the assessment includes classifying and determining the significance of cumulative effects from all previous, existing and future developments, including the NSDF Project (i.e., RFD Case). The classification of residual adverse effects and the determination of significance are completed only for those VCs that have assessment endpoints. Although the neutral and positive residual effects associated with the NSDF Project are reported in this section, they are not assessed for significance.

Magnitude is the primary criterion used to determine the significance of effects on VCs. Where possible and appropriate, established guidelines, thresholds and screening values are used to support the classification of the predicted amount of change in measurement indicators and associated effects on VC assessment endpoints. For some disciplines and VCs, such as aquatic health effects to fish, guideline or threshold values are known with reasonable certainty, which increases confidence in effects predictions and significance determinations. For other VCs of the biophysical and human environments, social and ecological benchmarks or effects thresholds are not known with reasonable certainty, which decreases confidence in determining the significance of predicted effects. For example, critical thresholds and screening levels for measurement indicators such as habitat quality, quantity and connectivity, and ecologically effective population sizes are frequently not available for plant, fish and wildlife species. Because of the uncertainty regarding the effects of development on VCs, magnitude classification is conducted conservatively to increase confidence that effects will not be under-estimated. Furthermore, the determination of significance considers the level of confidence in the effects predictions.

Magnitude also considers the geographic extent and duration of residual effects that are specific to VC assessment endpoints. For example, the magnitude of an effect on a fish or wildlife VC from changes in habitat availability and connectivity depends on the spatial extent (e.g., amount of area or proportion of the population) and duration of the changes in habitat (e.g., how long populations using that habitat may be adversely affected). Duration includes consideration of reversibility; a reversible effect from development does not result in a permanent adverse effect and therefore may be considered to be of lower magnitude. The duration of residual effects to VCs with high resilience (ability to recover from disturbance) would be expected to be shorter relative to VCs with lower resilience to disturbance.

Frequency and likelihood are considered as modifiers when determining significance, where applicable. For example, the magnitude of the effect from the loss of individuals from a wildlife population due to collisions with vehicles will depend partially on how often animal-vehicle collisions occur over the life of a project. For some effects, such as the physical loss of habitat from the NSDF Project footprint, the likelihood is high and has little influence on the significance of effects (i.e., the decline in habitat is certain and significance depends on the amount of change over space and time [magnitude]). Alternately, the magnitude of an effect may vary from low to high depending on the probability of different projected outcomes of climate change and the degree of success in actions implemented to mitigate effects from climate change.

The evaluation of significance for biophysical VCs considers the entire set of primary pathways that influence a particular assessment endpoint; thus, significance is not explicitly assigned to each pathway. Rather, the relative contribution of each pathway is used to determine the significance of potential adverse effects of the NSDF Project and other developments on an assessment endpoint. This approach is known as a “weight of evidence” approach (i.e., an evaluation of the persuasiveness of the collective evidence). For example, a pathway with a high magnitude (which would include a large geographic extent and a long-term duration) is given more weight in determining significance relative to pathways with smaller scale effects. The relative effect from each pathway is discussed; however, pathways that are predicted to have the greatest influence on effects to assessment endpoints are assumed to contribute the most to the determination of significance. This method is used to identify predicted residual adverse effects that have sufficient magnitude, duration and geographic extent to result in significant adverse effects on VC assessment endpoints.

Classification of residual effects and determination of significance for the human environment generally follow the methods used for biophysical VCs. However, there are some differences in the selection and definition of effects criteria. For socio-economic VCs, direction, magnitude, geographic extent and duration are the criteria used to classify effects and evaluate the significance of changes to assessment endpoints. The assessment of significance considers the scale of these criteria (e.g., low magnitude, regional geographic extent and long-term duration) and scientific knowledge and experience, which is based on the context of the communities involved, and the informed value and judgement of interested and affected organizations and specialists. The level of significance takes into consideration the effectiveness of the proposed mitigation (i.e., policies, practices and investments) and benefit enhancement programs to limit negative effects and foster positive effects on the continued persistence of long-term sustainable social, cultural and economic features of the human environment.

Details on the approach and methods for classifying residual effects and determining significance on VCs of the biophysical and human environments are provided in the applicable discipline sections of the EIS. The definition of a significant effect is specific to each discipline and will be provided in each discipline section. Significance is determined for the residual adverse effects of the NSDF Project overall, for the cumulative residual adverse effects from the NSDF Project and previous and existing developments (Application Case), and for the NSDF Project and previous, existing and reasonably foreseeable developments (RFD Case). The following is a summary of some of the key factors considered in the determination of significance on VCs of the biophysical and human environments.

- Results from the residual effects classification of primary pathways and associated predicted changes in measurement indicators.
- Magnitude is the primary criterion used to determine significance, with geographic extent and duration (which implies Reversibility) providing important context for assigning magnitude. Frequency and likelihood act as modifiers for determining significance, where applicable.
- The degree of uncertainty in the effects estimates also influences the classification of magnitude and the determination of significance. Where uncertainty was high and the effect might be either significant or not significant, the assessment conservatively identified the effect as significant and provided additional follow-up actions to reduce uncertainty.

5.1.9 Monitoring and Follow-up

In the EIS, monitoring programs are proposed to address the uncertainties associated with the effects predictions and the performance of mitigation. In general, monitoring is used to verify the effects predictions. Monitoring is used to identify any unanticipated effects and provide for the implementation of adaptive management to limit these effects. Typically, monitoring includes one or more of the following categories, which may be applied during the development of the NSDF Project.

- Compliance Monitoring – monitoring activities, procedures and programs undertaken to confirm the implementation of approved design standards, mitigation and conditions of approval, and company commitments (e.g., inspecting the installation of a silt fence).
- Environmental Monitoring – monitoring to track conditions or issues during the development lifespan of the NSDF Project, and to subsequently provide for the implementation of adaptive management (e.g., monitoring of treated wastewater discharge quality and volumes).
- Follow-up Monitoring – programs designed to test the accuracy of effects predictions, reduce or address uncertainties, determine the effectiveness of mitigation, or provide appropriate feedback to operations for modifying or adopting new mitigation designs, policies and practices (e.g., monitoring of downstream lakes for aquatic effects). Results from these programs can be used to increase the certainty of effect predictions in future environmental assessments.

Proposed monitoring and follow-up programs are discussed in each discipline section of the EIS and, upon Project approval, will be included in CNL's Environmental Management System or other appropriate CNL management, monitoring, or reporting programs. Where relevant, conceptual monitoring programs will be proposed to deal with the uncertainties associated with the effect predictions and mitigation.

5.2 Atmospheric Environment

This section of the Environmental Impact Statement (EIS) for the Canadian Nuclear Laboratories (CNL) Near Surface Disposal Facility (NSDF) Project seeks to understand and characterize potential residual effects of the NSDF Project and other past, present, and reasonably foreseeable developments on the atmospheric environment. As part of the assessment, the following subsections present an assessment of the atmospheric environmental effects of the NSDF Project. Section 5.2.1 focuses on air quality and Section 5.2.2 focuses on greenhouse gas (GHG) emissions. A quantitative noise and vibrations assessment has not been completed for inclusion in this EIS as there are not sensitive human receptors in the vicinity of the NSDF Project that would experience nuisance effects from the construction and operations phases of the NSDF Project. A discussion of potential effects from noise and vibrations is provided in Section 5.5 Aquatic Environment, Section 5.6 Terrestrial Environment and Section 5.11 Socio-economic Environment, with supporting information as required provided within those sections.

5.2.1 Air Quality

5.2.1.1 Scope of the Assessment

Section 5.2.1 focuses on air quality. The scope of the assessment focusses on predicting changes in indicator compounds emissions and comparison of these changes to the applicable guidelines and standards (see Section 5.2.1.4.). The indicator compounds emissions from the NSDF Project include suspended particulate matter (SPM), particles nominally smaller than 10 μm in diameter (PM_{10}), particles nominally smaller than 2.5 μm in diameter ($PM_{2.5}$), carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen oxides (NO_x) expressed as nitrogen dioxide (NO_2). Emissions of particulates (SPM, PM_{10}, and $PM_{2.5}$), CO, SO_2, and NO_x have the potential to affect aquatic, human, and terrestrial wildlife health. Particulates emissions, which are also referred to as fugitive dust, can also be a nuisance issue over which the public is concerned. In addition to the indicator compounds, hydrogen sulfide (H_2S), vinyl chloride (C_2H_3Cl), lead (Pb), mercury (Hg), and odour emissions have been considered as indicator compounds. Acrolein (C_3H_4O) was included to represent Volatile Organic Compounds (VOCs) from combustion at the request of CNSC. Radiological compounds are not included in this assessment and instead have been evaluated in Section 5.7 Ambient Radioactivity and Ecological Health.

The air quality assessment follows the overall environmental assessment approach and methods described in Section 5.1 Environmental Assessment Approach. The assessment is completed in the following key steps:

- **Step 1 – Identify Valued Components (VCs) and define the spatial boundaries, temporal boundaries, and assessment cases** for the air quality assessment (refer to Sections 5.2.1.2 Valued Components and Section 5.2.1.3 Assessment Boundaries). The VCs, assessment endpoints, and measurement indicators used to assess NSDF Project related changes to air quality; the spatial and temporal boundaries at which the assessment occurred; and, the assessment cases considered.
- **Step 2 – Describe the existing conditions** (refer to Section 5.2.1.4 Description of the Environment). Existing conditions in the local and regional areas are described, including the combined effects of previous and existing developments (Base Case). The existing environment represents the historical and current environmental pressures that have shaped the observed patterns in the environment (i.e., natural variation).

- **Step 3 – Evaluate Project interactions and mitigation** (refer to Section 5.2.1.5 Project Interactions and Mitigation). Project components and/or activities with the potential to affect air quality are identified and mitigation developed to limit or avoid effects is presented. A pathways analysis is then used to focus further assessment on key interactions between the NSDF Project and the environment by evaluating the different effect pathways to determine if, after incorporation of mitigation, there is still potential to cause residual effects. Where effects are adequately mitigated and are not forwarded for further analysis (i.e., secondary pathways, or where mitigation will remove the pathway altogether), the reasons for concluding the assessment at this stage are articulated. Primary pathways that may lead to residual effects to air quality after incorporating mitigation are carried forward to Steps 4 for further analysis and residual effects characterization.

- **Step 4 – Present the methods and results of the residual effects analysis** (refer to Section 5.2.1.6 Residual Effects Analysis). This section outlines the methods used to predict and characterize residual effects to air quality from primary effect pathways. The analysis results are also presented including the characterization of incremental effects from the NSDF Project, as well as cumulative effects of the Project in combination with other reasonably foreseeable developments (if applicable). A key outcome of this section is the predicted changes to emissions of indicator compounds that are passed on to other disciplines for their assessment.

- **Step 5 – Describe the level of certainty and management of uncertainty** (refer to Section 5.2.1.7 Prediction Confidence and Uncertainty). This purpose of this section is to evaluate the available literature, data, and models used for the assessment, and describe the level of certainty that can be placed on predicted residual effects. This section will also identify how the uncertainty has been managed so that the effects are not underestimated.

- **Step 6 – Classify and determine the significance of the predicted residual effects** (refer to Section 5.2.1.8 Residual Effects Classification and Determination of Significance). Residual effects predicted from primary pathways are classified using a common set of criteria: direction, magnitude, geographic extent, duration, reversibility, frequency, and likelihood. A determination of the significance of the predicted residual effects from NSDF Project for the air quality VC is made.

- **Step 7 - Identifying monitoring and follow-up** required to confirm effects predictions and address uncertainty (refer to Section 5.2.1.9 Monitoring and Follow-up).

- **Step 8 - Present a consolidated summary of conclusions and outcomes of the assessment** of residual effects on air quality (refer to Section 5.2.1.10 Conclusions).

Information and areas of interest raised by the public, communities of interest, regulators, and First Nations and Métis communities during engagement that influenced the scope of the air quality assessment are summarized in Table 5.2.1-1. Other general areas of interest and questions (if any) raised during the engagement that pertain to the air quality assessment are documented in Appendix 4.0-22 Formal Public Feedback.

Table 5.2.1-1: Summary of Areas of Interest Raised During Engagement Activities that Influenced the Scope of the Air Quality Assessment

Areas of Interest	How the Area of Interest Was Included in the Assessment
Would like information on monitoring air contamination.	The monitoring program proposed for air quality includes monitoring of fugitive dust emissions and is described in Section 5.2.1.9. Fugitive Dust Monitoring is captured through the implementation of CNL's Procedure for Management and Monitoring of Emissions, which includes operational control monitoring and air verification monitoring. In addition, the Dust Management Plan developed and implemented for the NSDF Project includes appropriate management techniques to control dust generated by the NSDF Project.

5.2.1.2 Valued Components

Valued components refer to environmental features that may be affected by a project and that have been identified to be of concern by the proponent, scientists, government agencies, First Nations and Métis communities, or the public (the Agency 2014). Air quality was selected as a VC as there is a potential for the NSDF Project activities to release air emissions that could affect the local air quality (Table 5.2.1-2). Meteorology is also important as it governs the transport, dispersion, and deposition of air emissions from the NSDF Project. An understanding of the local meteorological processes is necessary to address and model potential air quality effects of the NSDF Project. Details on meteorology are provided in Appendix 5.2-1.

Table 5.2.1-2: Valued Components for Air Quality Assessment

Valued Component	Rationale for Selection
Air Quality	■ Air quality is selected as a VC as emissions from the NSDF Project activities have the potential to alter the existing air quality regime. ■ Changes in air quality can affect human health, aquatic and terrestrial biodiversity.

Assessment endpoints are qualitative expressions used to assess the significance of residual effects on VCs and represent the key properties of the VC that should be protected for future generations. The assessment endpoint for air quality is performance against the criteria and thresholds for protection of human health and the environment.

Measurement indicators represent properties of the environment and VCs that, when changed, could result in or contribute to an effect on a VC. Measurement indicators also provide the primary factors for discussing the uncertainty of effects on VCs and, subsequently, are the key variables for study in follow-up and monitoring programs. The assessment of air quality focused on predicting changes in the concentrations of selected non-radiological indicator compounds. The measurement indicator considered in the air quality assessment includes changes to the concentrations of non-radiological indicator compounds listed in Table 5.2.1-3. Deposition rates for non-radiological compounds were also predicted and provided to other disciplines to assess the indirect effects of air quality. In addition, emissions from the decomposition of waste can be emitted as a result of breakdown of waste material within the NSDF; and therefore, is also included as indicator compounds. These compounds are generally accepted as indicative in changing air quality, and for which relevant air quality criteria exist. The selected non-radiological indicator compounds fall into the following four categories:

- **particulate matter**: SPM, PM_{10}, and $PM_{2.5}$;
- **combustion gases**: NO_X represented by NO_2, SO_2, CO, and C_3H_4O;
- **decomposition of waste**: H_2S, C_2H_3Cl, and odour; and,
- **metals**: Pb and Hg.

These compounds are associated with various NSDF Project activities, as well as activities at the CRL main campus. Particulate matter in the form of fugitive dust is typically associated with airborne dust from vehicles travelling on on-site unpaved roads/haul routes, as well as material loading, stockpiling and unloading activities. Products of combustion (e.g., particulate matter, NO_2, SO_2, CO, and Pb) are associated with the exhaust from on-site vehicles and stationary combustion from the WWTP process and comfort heating equipment. In addition, C_3H_4O (acrolein) was included to represent Volatile Organic Compounds (VOCs) from combustion. Emissions from the decomposition of waste (e.g., H_2S, C_2H_3Cl, and odour) were not included in the Annual Safety Report Effluent Verification Monitoring at Chalk River Laboratories in 2015 (CNL 2016), but are the result of breakdown of waste material within the NSDF Project; and therefore, included as indicator compounds.

Other contaminants identified as indicator compounds that occur from the decomposition of the waste in the engineered containment mound (ECM), such as CO and Hg were also included. Odour emissions from the WWTP processes were also included. Metals are associated with number 6 fuel oil consumption at the CRL main campus (CNL 2016), and are expected to decrease before the operation of the NSDF due to ongoing facility improvements, such as the conversion from fuel oil heating to natural gas heating. Total VOCs and halocarbon refrigerants are not considered indicator compounds; and therefore, were not retained for the air quality effects assessment. Ozone (O_3) was also included in the air quality baseline assessment as it will be used to calculate the NO_2 in the effects assessment. Ozone is not emitted directly into atmosphere but is associated with the reaction of NO_X and VOCs (MOECC 2015).

The measurement indicators used for assessing the effects of the NSDF Project on the air quality VC are a combination of indicator compound and averaging period for which federal and provincial air quality objectives and criteria are available. A single measure is used when evaluating effects, namely the maximum predicted concentration resulting from the NSDF Project activities. To evaluate the effect of project-related changes to air quality on other VCs, the results of the air quality assessment were provided to the disciplines listed in Table 5.2.1-3.

Table 5.2.1-3: Assessment Endpoints and Measurement Indicators for the Air Quality Assessment

Valued Component	Assessment Endpoints	Measurement Indicators	Discipline Assessments where Effects on Air Quality are Considered
Air Quality	Performance against criteria and thresholds for protection of human health and the environment	Changes to ambient concentrations of indicator compounds (SPM, PM_{10}, $PM_{2.5}$, NO_2, SO_2, CO, C_3H_4O, H_2S, C_2H_3Cl, Pb, Hg, and odour).	■ Surface Water Quality (Section 5.4.2) ■ Aquatic Environment (Section 5.5) ■ Terrestrial Environment (Section 5.6) ■ Human Health (Section 5.8) ■ Land and Resource Use (Section 5.9)

SPM = suspended particulate matter; $PM_{2.5}$ = particulate matter less than 2.5 µm (microns) in diameter; PM_{10} = particulate matter less than 10 µm (microns) in diameter; CO = carbon monoxide; NO_2 = nitrogen dioxide; SO_2 = sulphur dioxide; CO = carbon monoxide; C_3H_4O = acrolein; H_2S; = hydrogen sulfide; C_2H_3Cl = vinyl chloride; Pb = lead; Hg = mercury.

5.2.1.3 Assessment Boundaries

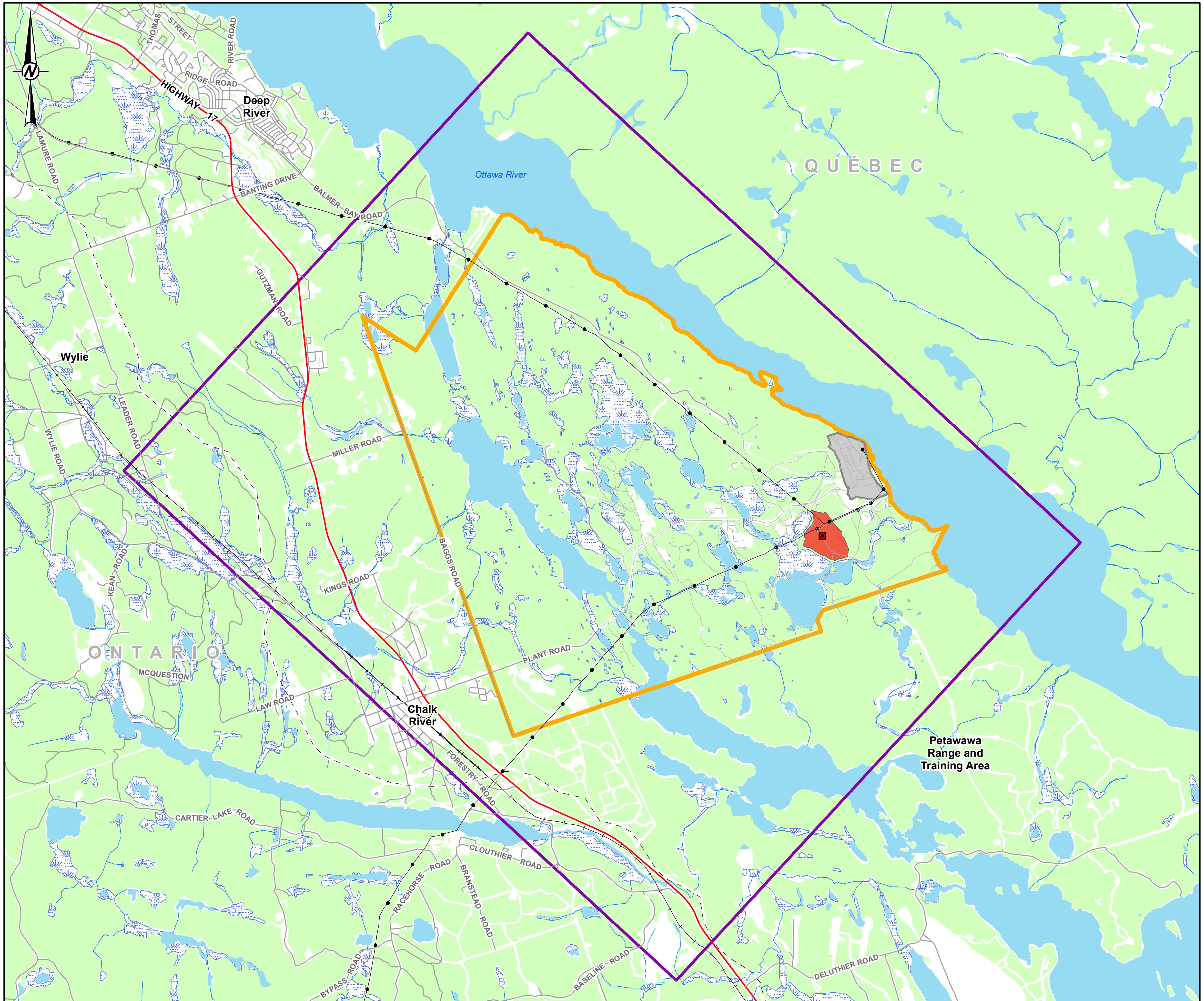
5.2.1.3.1 Spatial Boundaries

The spatial boundaries selected for the air quality assessment are presented on Figure 5.2.1-1 and are described below:

- **Site Study Area (SSA):** the SSA is the NSDF Project footprint (i.e., where Project activities would be undertaken including the NSDF Project's proposed facilities, buildings and infrastructure).
- **Local Study Area (LSA):** The LSA is defined to encompass activities and sources of emissions associated with the Project. The LSA includes the SSA and corresponds to the Chalk River Laboratories (CRL) property boundary.
- **Regional Study Area (RSA):** The RSA is defined as the area within which the potential effects of the NSDF Project may interact with the effects of other existing or reasonably foreseeable projects. The RSA is equivalent to approximately a 10 kilometre (km) by 10 km rectangle surrounding the LSA, and oriented parallel to the Ottawa River (Figure 5.2.1-1).

For the purposes of this assessment, results at the LSA boundary will be presented in the air quality effects assessment as it is represents the highest ground-level concentrations of contaminants expected outside the CRL property.

This page left intentionally blank



LEGEND

- HIGHWAY
- ROAD
- RAILWAY
- TRANSMISSION LINE
- NATURAL GAS PIPELINE
- RIVER/STREAM
- WATERBODY
- WETLAND
- WOODED AREA
- NEAR SURFACE DISPOSAL FACILITY (NSDF) PROJECT CENTROID
- SITE STUDY AREA (NSDF PROJECT SITE)
- CRL MAIN CAMPUS
- LOCAL STUDY AREA (CRL PROPERTY)
- REGIONAL STUDY AREA

2.5 0 2.5
1:60,000 KILOMETRES

REFERENCE(S)

1. BASEMAP:SOURCES: ESRI, HERE, DELORME, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), SWISSTOPO, MAPMYINDIA, © OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
2. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
3. HIGHWAYS AND FIRST NATION RESERVES MNRF 2016
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE18N

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
SPATIAL BOUNDARIES SELECTED FOR THE ATMOSPHERIC ENVIRONMENT ASSESSMENT

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	EM
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0001	0.0	5.2.1-1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:

This page left intentionally blank

5.2.1.3.2 Temporal Boundaries

Temporal boundaries (i.e., project phases) establish the timeframe during which NSDF Project effects are assessed. The temporal boundary represents the timeframe during which project activities are actively occurring, and considers the duration of predicted residual effects. The duration of an effect is defined as the amount of time between the start and end of a Project activity or stressor (which is related to the project phases) plus the time required for the residual effect to be reversed. In some cases, a residual effect may be irreversible within the temporal boundaries of the Project or if the effects were predicted to last so far into the future that the level of uncertainty (e.g., residual effect lasts for thousands of years). The following phases were identified for the NSDF Project:

- **Construction Phase**: includes site preparation and all activities associated with the construction of the NSDF. This phase includes activities such as installing the necessary supporting and/or ancillary facilities and NSDF infrastructure to facilitate NSDF operations, inactive commissioning and systems testing, and transportation of construction materials. Construction activities are expected take place from 2018 to 2020.
- **Operations Phase**: includes all activities associated with the waste receipt, waste placement, water management, wastewater treatment plant operations, vehicle movements into and from the NSDF Project site, and maintenance activities. The operations phase is expected to last approximately 50 years (i.e., 2020 to 2070).
- **Closure Phase:** includes activities necessary to complete the installation of the final cover and implementation of long-term monitoring. Closure activities are expected to start in 2070 and continue through to 2100, after which the NSDF Project will transfer into the post-closure phase.
- **Post-closure Phase:** has two discrete periods: Institutional Control and post-Institutional Control. The Institutional Control period includes implementation of both active and passive control throughout 2100 to 2400 (i.e., 300 years). During Institutional Control, groundwater monitoring and groundwater quality management will continue to demonstrate compliance with the safety case assumptions. Post-institutional Control occurs after year 2400 and continues indefinitely.

For the purposes of the air quality assessment, only the construction and operation phases have been considered as the emissions from these phases will be higher than those during the closure and post-closure phases. Emissions from the construction phase are expected to be representative of those during closure as they will be similar in nature. The emissions from the closure phase are expected to be considerably less than those during the construction and operation phases, as the most of the NSDF Project site will have been decommissioned. Effects to air quality would immediately cease following decommissioning of the WWTP and associated water management systems at the end of the closure phase.

5.2.1.3.3 Assessment Cases

The assessment cases considered in the air quality assessment include the Base Case and the Application Case:

- **Base Case –** This scenario represents existing conditions and characterizes effects from previous and existing developments and activities. The Base Case reflects the effects of existing disturbances in the area, such as forestry, transportation, agricultural, mining, and residential and recreational development. For example, current effects from the existing operations and activities on the CRL property are considered part of the Base Case.
- **Application Case –** This scenario represents the effects of the Base Case combined with the predicted effects that from the NSDF Project. The Application Case was divided into the construction phase and the operations phase, and therefore, the emissions and associated effects during the construction and operations phases of the NSDF Project represent the bounding cases.
- **Reasonably Foreseeable Development (RFD) Case** – There are no foreseeable developments expected in the region other than the decommissioning of the remaining CRL structures. No known reasonably foreseeable future developments have been identified within 10 km of the CRL site (i.e., the air quality RSA). The waste from the decommissioning of the CRL structures will be placed in the NSDF and the Application Case for the operations phase considers the transport of this waste for disposal in the ECM. New/upgrades to research and development facilities, new support infrastructure and decommissioning activities will involve similar equipment used during the construction phase of the NSDF Project, and are expected implement similar mitigation to limit vehicle and equipment exhaust, and fugitive dust. Consequently, the Application Case construction phase is considered to capture the effects from the decommissioning of the CRL structures.

5.2.1.4 Description of the Environment

5.2.1.4.1 Methods

This section documents the methods, data, and assumptions that were used to assess the non-radiological background air quality at the NSDF Project and in the LSA and RSA. The assessment was carried out by:

- identifying the non-radiological indicator compounds expected to be emitted from the NSDF Project;
- identifying and comparing non-radiological air quality guidelines in Ontario and Canada for the indicator compounds;
- identifying existing emission sources located within 25 km of the LSA with shared indicator compounds;
- assessing air quality data sources for use in the background air quality assessment; and,
- comparing air quality monitoring data to the applicable air quality guidelines.

These steps are detailed in the following sections.

Applicable Criteria

The relevant air quality criteria used for screening air quality in the region include the Ontario criteria, and federal standards and objectives where provincial guidelines are not available. The Ontario Ministry of the Environment and Climate Change (MOECC) has set guidelines related to ambient air concentrations and are summarized in Ontario's Ambient Air Quality Criteria (AAQC) document (MOECC 2012). The Ontario AAQCs are characterized as desirable ambient air concentrations and have been set at levels that are protective of human health and the environment. The Ontario AAQCs are not regulatory limits, and therefore, exceedances are permitted. The Ontario AAQCs are used for screening the air quality effects in environmental assessments, in studies using ambient air monitoring data, and as an assessment of general air quality in a community or across the province (MOECC 2012).

Where provincial criteria were not available, the National Ambient Air Quality Objectives (NAAQOs) and the Canadian Ambient Air Quality Standards (CAAQSs; formerly NAAQS) were used. There are two sets of federal objectives and criteria: the National Ambient Air Quality Objectives (NAAQOs) and the Canadian Ambient Air Quality Standards (CAAQSs; formerly National Ambient Air Quality Standards [NAAQS]). Similar to the Ontario AAQCs, the NAAQOs are benchmarks that can be used to facilitate air quality management on a regional scale, and provide goals for outdoor air quality that protect public health, the environment, or aesthetic properties of the environment (CCME 1999). The federal government has established the following levels of NAAQOs (Health Canada 1994):

- the maximum ***Desirable*** level defines the long-term goal for air quality and provides a basis for an anti-degradation policy for unpolluted parts of the country and for the continuing development of control technology; and,
- the maximum ***Acceptable*** level is intended to provide adequate protection against adverse effects on soil, water, vegetation, materials, animals, visibility, personal comfort, and well-being.

The CAAQSs have been developed under the *Canadian Environmental Protection Act* (CEPA), and include standards for $PM_{2.5}$ and ozone that must be achieved by 2020. In 2015 the standard was phased in, with the final standard phase in date in 2020 (Government of Canada 2013). Like the Ontario AAQCs, the CAAQSs are not regulatory limits and are used as national targets for $PM_{2.5}$ and ozone, excluding Quebec (CCME 2014).

A summary of the applicable Ontario and federal objectives and criteria are listed in Table 5.2.1-4.

Table 5.2.1-4: Provincial and Federal Regulatory Air Quality Criteria

Substance	Averaging Period	Ontario Ambient Air Quality Guidelines[(a)] ($\mu g/m^3$)	Canadian Ambient Air Quality Standards[(b)] ($\mu g/m^3$)	National Ambient Air Quality Objectives and Canadian Ambient Air Quality Standards[(c)] ($\mu g/m^3$)	
				Desirable	Acceptable
SPM[(d)]	24-Hour	**120**	—	—	120
	Annual	**60[(e)]**	—	60	70
PM_{10}	24-Hour	**50[(f)]**	—	—	—
$PM_{2.5}$	24-Hour	**30[(g)]**	27	—	—
	Annual	—	**8.8**	—	—
NO_2	1-Hour	**400[(h)]**	—	—	400
	24-Hour	**200[(h)]**	—	—	200
	Annual	—	—	**60**	100
SO_2	1-Hour	**690**	—	450	900
	24-Hour	**275**	—	150	300
	Annual	**55**	—	30	60
CO	1-Hour	**36,200**	—	15,000	35,000
	8-Hour	**15,700**	—	6,000	15,000
C_3H_4O	1-Hour	**4.5**	—	—	—
	24-Hour	**0.4**	—	—	—
O_3	1-Hour	165	—	100	160
	8-Hour	—	62	—	—
Pb	24-Hour	**0.5**	—	—	—
	30-Day	**0.2[(i)]**	—	—	—
Hg	24-Hour	**2**	—	—	—
H_2S	10-Minute	**13**	—	—	—
	24-Hour	**7**	—	—	—
C_2H_3Cl	24-Hour	**1**	—	—	—
Odour (OU/m^3)	10-minute	**1[(j)]**	—	—	—

a) Ontario Ministry of the Environment and Climate Change (MOECC 2012).

b) Canadian Ambient Air Quality Standards published in the Canada Gazette Volume 147, No. 21 - May 25, 2013. Final standard phase in date of 2020 used.

c) Canadian Council of Ministers of the Environment (CCME 1999).

d) SPM in Ontario is defined as <44 µm diameter.

e) Geometric mean.

f) Interim Ambient Air Quality Criteria and is provided as a guide for decision making (MOECC 2012).

g) Compliance is based on the 98th percentile of the annual monitored data averaged over three years of measurements.

h) Standard is for nitrogen oxides (NO_X), but is based on the health effects of NO_2.

i) Arithmetic mean.

j) The Ontario Guideline is based on the 99.5th percentile on a 10-minute averaging period, in OU/m^3 (MOECC 2008).

Note:

Bold = ambient air criteria retained for use in the assessment.

— = No guideline available; SPM = suspended particulate matter; $PM_{2.5}$ = particulate matter less than 2.5 µm (microns) in diameter; PM_{10} = particulate matter less than 10 µm (microns) in diameter; CO = carbon monoxide; NO_2 = nitrogen dioxide; SO_2 = sulphur dioxide; CO = carbon monoxide; H_2S; = hydrogen sulfide; C_2H_3Cl = vinyl chloride; Pb = lead; Hg = mercury; $\mu g/m^3$ = microgram per cubic metre; OU/m^3 = odour unit per cubic metre.

Existing Emissions Sources

There are two industrial facilities, the CRL main campus and the Department of National Defence, that report indicator compounds and pollutant releases, disposals, and transfers for recycling under Part 1A to the National Pollutant Release Inventory (NPRI) within 25 km of the LSA (ECCC 2016). The only facility within the RSA is the CRL main campus. These emissions contribute to the local air quality and the consideration of effects from the NSDF Project. The reporting facilities and emission totals are summarized in Table 5.2.1-5. In general, these sources are minor contributors of the non-radiological indicator compounds, with the exception of the lead emissions from the Department of National Defence.

Table 5.2.1-5: 2014 Air Emission Totals for Industries within 25 km of the Local Study Area

Company Name	Distance to the NSDF Project[a] (km)	Direction from the NSDF Project	Emissions[b] (tonnes)						Emissions[b] (kg)	
			NO_X	SO_2	CO	SPM	PM_{10}	$PM_{2.5}$	Hg	Pb
Canadian Nuclear Laboratories	1	North	65.124	223.901	—	33.098	19.220	10.523	0.145	2.042
Department of National Defence	16	Southeast	37.537	—	35.391	—	2.2	1.459	—	20.404

a) Distance from the NSDF Project footprint centroid.

b) ECCC 2016.

— = Not available; km = kilometre; kg = kilogram; SPM = suspended particulate matter; $PM_{2.5}$ = particulate matter less than 2.5 µm (microns) in diameter; PM_{10} = particulate matter less than 10 µm (microns) in diameter; CO = carbon monoxide; NO_2 = nitrogen dioxide; SO_2 = sulphur dioxide; CO = carbon monoxide; H_2S; = hydrogen sulfide; C_2H_3Cl = vinyl chloride; Pb = lead; Hg = mercury.

Baseline Air Quality Data

Although air quality data is provided in the CRL 2015 Effluent Verification Monitoring Report (CNL 2016), the data is based on emission estimates (emission factors), rather than monitored data, and represents emissions solely from the CRL main campus. Other industries outside the RSA are not considered in the baseline and, therefore, data from monitored data sources was used and is considered to be more representative of background air quality. Site-specific air quality monitoring was not carried out as part of this assessment.

Therefore the background air quality was assessed using observations from the ECCC National Air Pollution Surveillance Network (NAPS) air quality monitoring stations (ECCC 2013) at locations outside the RSA (Appendix 5.2-2). Data from the Canadian Air and Precipitation Monitoring Network (CAPMoN) network was received from ECCC for the station located at the CRL site (CAPMCAON1CHA); however due to limited data availability (only 2009 to 2011 and only certain indicator compounds) the data was not considered for the air quality baseline assessment. The closest air quality monitoring station otherwise is located in Petawawa, however not all indicator compounds are monitored at the Petawawa station. The next closest air quality monitoring station with additional indicator compounds is the Ottawa Downtown monitoring station. Some indicator compounds (C_3H_4O, Hg, H_2S, C_2H_3Cl, and odour) were not monitored at either monitoring station. The specific stations selected to describe the existing air quality regime are presented in Table 5.2-1-6, and are illustrated on Figure 5.2.1-2.

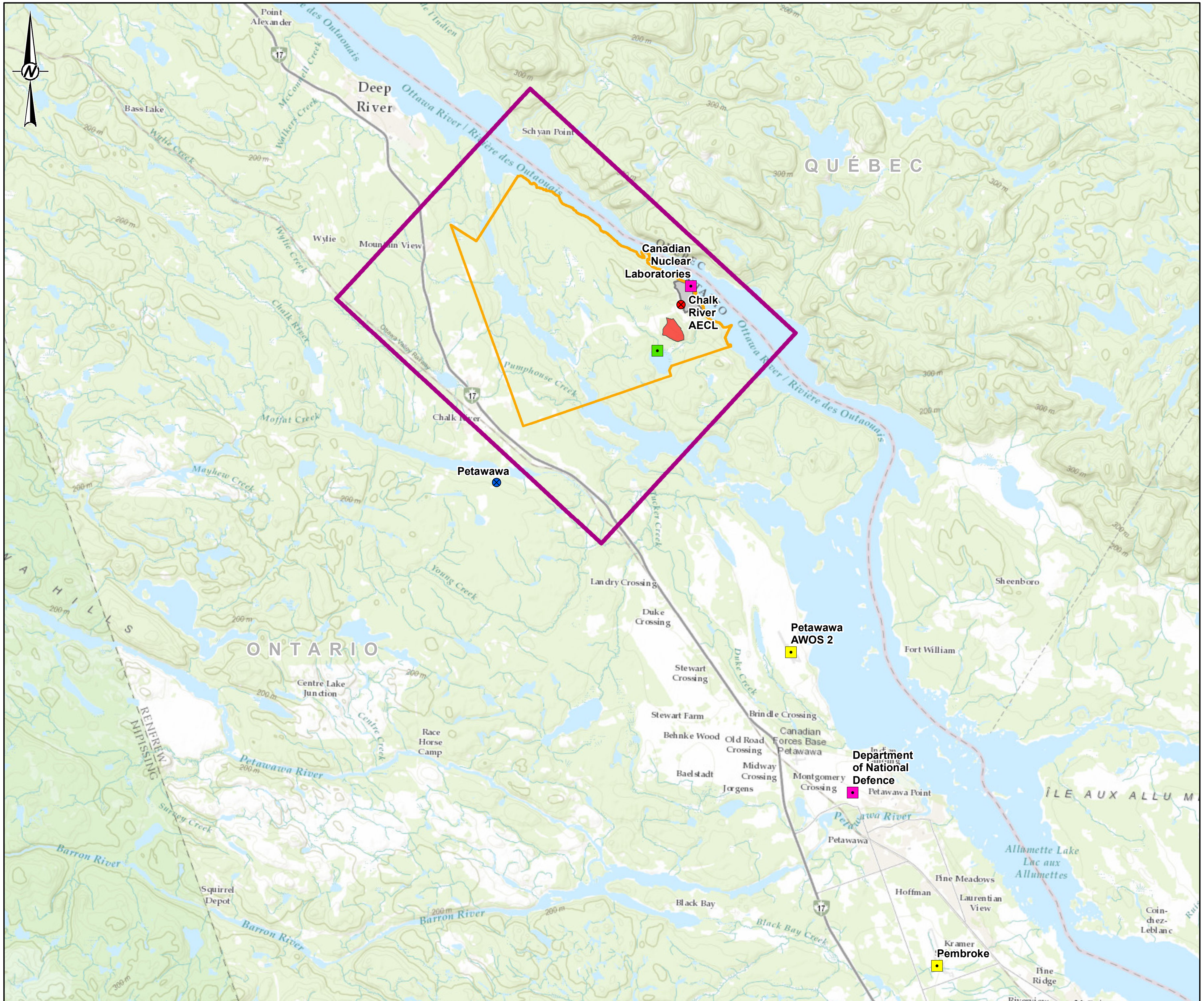
Table 5.2.1-6: Location of Air Monitoring Stations

City	NAPS Station Identification	Location	Latitude and Longitude	Distance to the NSDF Project[a] (km)	Direction
Petawawa	66201	Outside Regional Study Area	45.996722, -77.441194	7	South-southwest, generally downwind
Ottawa Downtown	60104	Outside Regional Study Area	45.43433, -75.676	148	Southeast, generally upwind

a) Distance from the NSDF Project footprint centroid.
NAPS = National Air Pollution Surveillance Network; km = kilometre.

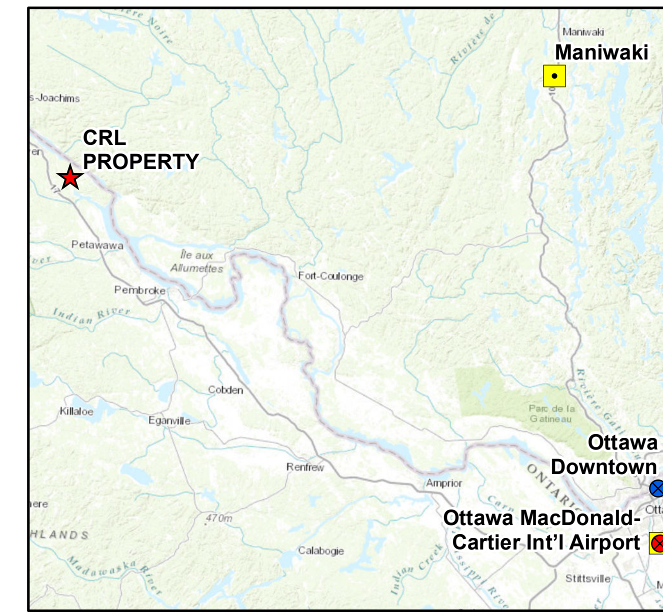
The wind direction into the Chalk River area is predominantly from the southeast (Appendix 5.2-1). The air quality monitoring station in Ottawa Downtown (NAPS ID 60104) captures this air flow into Chalk River; however, the station is located approximately 150 km from the NSDF Project site. The results can be considered to provide conservative air quality estimates (likely to be greater than the existing conditions in the RSA) given its urban location. The Petawawa station (NAPS ID 66201) is generally downwind of the NSDF Project and is considered to be the most representative station of the RSA, due to proximity and similarity in geographic siting (rural location and distance from the Ottawa River). The majority of the stations located outside the 100 km radius only monitor $PM_{2.5}$ and O_3. As mentioned above, the closest station that monitors some of the remaining indicator compounds is the Ottawa Downtown station.

There is no monitoring data available for SPM and PM_{10} at the Petawawa station, however, an estimate of the background SPM and PM_{10} concentrations can be estimated from the available $PM_{2.5}$ monitoring results. $PM_{2.5}$ is a subset of PM_{10}, and PM_{10} is a subset of SPM. Therefore, it is reasonable to assume that the ambient concentrations of SPM will be greater than corresponding PM_{10} levels, and PM_{10} concentrations will be greater than the corresponding levels of $PM_{2.5}$. The mean levels of $PM_{2.5}$ in Canadian locations are found to be about 50% of the PM_{10} concentrations and about 25% of the SPM concentrations (Brook et al. 2011). By applying this ratio, it is possible to estimate the background SPM and PM_{10} concentrations for the RSA.



LEGEND
- CRL ENVIRONMENTAL MONITORING STATION
- AMBIENT AIR QUALITY MONITORING STATION
- NPRI REPORTING FACILITY
- CLIMATE NORMALS STATION
- METEOROLOGICAL STATION
- SITE STUDY AREA (NSDF PROJECT SITE)
- CHALK RIVER LABORATORIES (CRL) MAIN CAMPUS
- LOCAL STUDY AREA (CRL PROPERTY)
- REGIONAL STUDY AREA

REGIONAL AMBIANT AIR MONITORING STATION



5 0 5
1:125,000 KILOMETRES

REFERENCE(S)
1. BASEMAP:SOURCES: ESRI, HERE, DELORME, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), SWISSTOPO, MAPMYINDIA, © OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
2. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
3. HIGHWAYS AND FIRST NATION RESERVES MNRF 2016
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18N

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
AMBIENT AIR QUALITY MONITORING STATIONS AND NPRI REPORTING FACILITIES

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	EM
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0001	0.0	5.2.1-2

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm

Path: S:\Clients\Canadian_Nuclear_Laboratories\NSDF\99_PROJ\1547525_NSDF_EIS\40_PROD\0009_EIS_Section_5\Section_5_2_Atmospheric\1547525-0009-RN-0002.mxd

This page left intentionally blank

5.2.1.4.2 Results

Table 5.2.1-7 provides a summary of the existing air quality data based on Petawawa station and the Ottawa Downtown stations, for consideration in the Base Case. Due to proximity and similarity in geographic siting (rural location and distance from the Ottawa River), the Petawawa station is considered to be the most representative station of the RSA, and therefore represents the background for indicator compounds monitored at that station. For some of the remaining indicator compounds, monitored data from the Ottawa Downtown have been used in the background although the station is located approximately 150 km from the NSDF Project site. The results from the Ottawa Downtown station can be considered to provide conservative air quality estimates (likely to be greater than the existing conditions in the RSA) given its urban location.

The data presented in Table 5.2.1-7 represent the 90th percentile of the 1-hour, 8-hour, and 24-hour monitored data; a value usually considered to be an appropriate representation of background concentrations from measured data (Alberta Environment and Sustainable Resource Development 2013). The annual average is used for the annual background concentrations. The existing concentrations are below the respective provincial and federal criteria for each indicator compound, suggesting that the region has generally good air quality (Table 5.2.1-7).

Table 5.2.1-7: Background Air Quality Values (90th Percentile, Average for Annual Only)

Indicator	Averaging Period	Background [µg/m³]	Petawawa (7 km SSW) [µg/m³]	Ottawa Downtown (148 km SE) [µg/m³]
SPM	24-hour	**30.95**	**30.95**	41.50
	Annual	**14.53**	**14.53**	20.68
PM_{10}	24-hour	**15.48**	**15.48**	20.75
$PM_{2.5}$	24-hour	**7.74**	**7.74**	10.38
	Annual	**3.63**	**3.63**	5.17
NO_2	1-Hour	**31.98**	—	**31.98**
	24-Hour	**28.61**	—	**28.61**
	Annual	**14.86**	—	**14.86**
SO_2	1-Hour	**2.62**	—	**2.62**
	24-Hour	**2.62**	—	**2.62**
	Annual	**1.05**	—	**1.05**
CO	1-Hour	**458.10**	—	**458.10**
	8-Hour	**486.73**	—	**486.73**
C_3H_4O	1-Hour	—	—	—
	24-Hour	—	—	—
Pb	24-Hour	**0.0046**	—	**0.0046**
	30-Day	—	—	—
Hg	24-Hour	—	—	—
H_2S	10-Minute	—	—	—
	1-Hour	—	—	—
C_2H_3Cl	24-Hour	—	—	—
Odour (OU/m³)	10-Minute	—	—	—

Note:

Bolded values represent the background air quality.

SSW = south-southwest; SE = southeast; — = No monitored data available; km = kilometre; kg = kilogram; SPM = suspended particulate matter; $PM_{2.5}$ = particulate matter less than 2.5 µm (microns) in diameter; PM_{10} = particulate matter less than 10 µm (microns) in diameter; CO = carbon monoxide; NO_2 = nitrogen dioxide; SO_2 = sulphur dioxide; CO = carbon monoxide; H_2S; = hydrogen sulfide; C_2H_3Cl = vinyl chloride; Pb = lead; Hg = mercury.

5.2.1.5 Project Interactions and Mitigation

5.2.1.5.1 Methods

This section describes the process by which interactions between NSDF Project components and activities and air quality were identified and evaluated. Potential effect pathways are identified and mitigation developed to eliminate and/or reduce effects is presented. A pathways analysis is then used to focus the assessment on key interactions between the NSDF Project and the environment by evaluating the different effect pathways to determine if, after incorporation of mitigation, there is still potential to cause residual effects. Where effects will be adequately mitigated and are not forwarded for further analysis (i.e., secondary pathways, or where mitigation will remove the pathway altogether), the reasons for concluding the assessment at this stage are articulated. Primary pathways that may lead to residual effects after incorporation of mitigation are further characterized in subsequent subsections of the assessment (i.e., Section 5.2.1.6). As such the 'Project Interactions and Mitigation' section helps to focus the remainder of the assessment on those interactions (effects pathways) likely to result in residual adverse effects.

The first part of the analysis was to identify the potential effects pathways for all stages of the NSDF Project. The next step in the analysis was the development of environmental design features and mitigation practices that could be incorporated into the NSDF Project to eliminate and/or reduce effects to air quality. Environmental design features included design elements, environmental best practices, and management policies and procedures. Environmental design features and mitigation were developed through an iterative process between the engineering and environmental teams, combined with input from project-specific or regional engagement with other interested parties. The design features and/or mitigation were selected considering their effectiveness for implementation and maintenance, and their appropriateness within the context of the identified effect pathways.

After incorporation of mitigation, potential pathways were evaluated into the following categories using scientific knowledge, logic, experience with similar developments, and the effectiveness of environmental design features and mitigation:

- **No pathway –** pathway is removed by environmental design features or mitigation such that the NSDF Project would not be expected to result in a measurable environmental change to concentrations of indicator compounds relative to Base Case values, and therefore would have no residual effects to air quality.
- **Secondary pathway –** the pathway could result in a measurable minor change to concentrations of indicator compounds, but would have a negligible residual effect on air quality relative to Base Case and/or guideline values and is not expected to contribute cumulatively to other NSDF Project effects or to the effects of other past, present or reasonably foreseeable developments to cause a significant effect.
- **Primary pathway –** the pathway is likely to result in an environmental change to concentrations of indicator compounds relative to the Base Case and/or guideline values that could contribute to residual effects to air quality.

Environmental design features and mitigation that have been or could be incorporated into the NSDF Project to eliminate and/or reduce adverse effects to air quality were considered. Potential pathways that were completely removed due to implementation of environmental design or mitigation were not assessed further. Pathways that were assessed to be secondary and demonstrated to have a negligible residual effect to air quality through simple qualitative or semi-quantitative evaluation of the pathway were also not advanced for further assessment.

Primary pathways were carried forward for more detailed quantitative and qualitative effects analysis to characterize the residual effects of the NSDF Project on air quality.

5.2.1.5.2 Results

The potential pathways from sources of air emissions to air quality are dependent on the presence and relative intensity of the activity over the various NSDF Project phases. Activities associated with the construction and operation of the ECM including emissions from the decomposition of waste, the WWTP and its operation, vehicle movements on unpaved surfaces, wind erosion of stockpiles, and emissions from support activities, such as stationary combustion sources, would emit indicator compounds. Each activity or source would have a different level of intensity or use a different amount of equipment depending on the phase in which the activity occurred. Pathways through which all stages of the NSDF Project may interact with and result in changes to concentrations of indicator compounds is provided in Table 5.2.1-8.

Table 5.2.1-8: Pathways Analysis for Air Quality Valued Component

NSDF Project Activity	Effects Pathways	Management Practices and Mitigation Actions	Pathway Assessment
Construction ■ Site preparation ■ Construction of the ECM ■ Development of surface water management structures ■ Construction of the WWTP and other support facilities ■ On-site road and access development	Construction activities use vehicles and equipment that combust fuel and emit indicator compounds. These activities involve material handling, vehicles travelling on unpaved roads, and wind erosion of stockpiles that will result in fugitive dust emissions.	■ Implementation of Canadian Nuclear Laboratories' (CNL) Procedure for Management and Monitoring of Emissions, which includes operational control monitoring and air verification monitoring. ■ The Dust Management Plan for the NSDF Project will be developed and will include: ▪ Restricting or suspending activities if unacceptable amounts of dust are generated due to winds or other site conditions. ▪ Use of water spraying or misting techniques (e.g., water trucks) as the primary dust control method; ▪ Use of fixatives (e.g., chemical suppressant) for dust control during winter season or shutdown periods, and for use as daily/interim cover. ▪ Suspension of excavating, loading, hauling, and dumping operations when wind speeds exceed the specified criterion. ▪ Vehicles that have come into contact with contamination will be required to pass through the vehicle decontamination facility. ■ On-site vehicles and equipment engines will meet Tier 2 emission standards and be maintained in good working order. ■ Limit idling of vehicles on-site.	Primary pathway

Table 5.2.1-8: Pathways Analysis for Air Quality Valued Component

NSDF Project Activity	Effects Pathways	Management Practices and Mitigation Actions	Pathway Assessment
Operations ■ Staged development of ECM disposal cells ■ On-site transportation of waste and placement of waste in the ECM ■ Progressive closure of disposal cells and installation of cover ■ Operation of the WWTP	■ Most activity and material handling occurs during the operations phase, and pathways include: ▪ vehicles and equipment combust fuel and emit indicator compounds; ▪ material handling, vehicles travelling on unpaved roads, and wind erosion of stockpiles emit fugitive dust; ▪ the disposal cell cover and passive vents and the WWTP emit odour. ■ Release of emissions from the operation of the WWTP.	■ Implementation of Canadian Nuclear Laboratories' (CNL) Procedure for Management and Monitoring of Emissions, which includes operational control monitoring and air verification monitoring. ■ The Dust Management Plan for the NSDF Project will be developed and will include: ▪ Restricting or suspending activities if unacceptable amounts of dust are generated due to winds or other site conditions. ▪ Use of water spraying or misting techniques (e.g., water trucks) as the primary dust control method. ▪ Use of fixatives (e.g., chemical suppressant) for dust control during winter season or shutdown periods, and for use as daily/interim cover. ▪ Suspension of excavating, loading, hauling, and dumping operations when wind speeds exceed the specified criterion. ▪ Vehicles that have come into contact with contamination (i.e., will be required to pass through the vehicle decontamination facility). ■ On-site vehicles and equipment engines will meet Tier 2 emission standards and be maintained in good working order. ■ Limit idling of vehicles on-site. ■ Processed leachate will not be heated within the WWTP ■ There is active ventilation within the WWTP building and all emissions to air will be filtered prior to release.	Primary pathway
Operations and Post-closure ■ Placement of waste in the ECM	Air emissions from the decomposition of waste.	Installation of the final disposal cell cover will reduce release of emissions from the ECM.	Primary pathway

5.2.1.6 Residual Effects Analysis

5.2.1.6.1 Methods

Residual effects of the NSDF Project are those effects that remain after implementation of all mitigation. The assessment of effects of the NSDF Project on the air quality involves two steps, namely the calculation of emission rates and use of dispersion modelling to predict the resulting concentrations of indicator compounds. These steps are described below.

Emissions Quantification

The method used for calculating and quantifying air emissions resulting from the NSDF Project involved the following steps:

- **Identifying emissions sources:** Emission sources were identified based on the NSDF Project conceptual design and the project information provided in the Project Description (Section 3.0).
- **Calculating emission rates:** Air emission rates were calculated using accepted methods, such as emission factors, and were based on activity data provided in the Project Description (Section 3.0), as well as LandGEM and MOBILE6.2.C modelling results provided in Appendix 5.2-3. Emission rates were calculated for the Application Case scenario for both the construction and operations phases.
- **Summarizing overall emissions:** The calculated emissions were summarized by activity type.

The emission estimation methods used in the air quality assessment follow generally accepted practices for conducting environmental assessments and, where appropriate, guidance in the MOECC document *"Procedure for Preparing an Emission Summary and Dispersion Modelling Report"* Version 3.0 (MOECC 2009). Details of the specific emission calculation methods and resulting emissions are provided in Appendix 5.2-3.

Dispersion Modelling

Models were used to predict ground-level concentrations of non-radiological indicator compounds. The AERMOD dispersion model (Version 15181) was used to predict concentrations and deposition rates associated with NSDF Project emissions. The AERMOD dispersion modelling system was developed by the United States Environmental Protection Agency (U.S. EPA) as a replacement to the long-standing Industrial Source Complex (ISC) model (U.S. EPA 2004), and is the model recommended by the U.S. EPA for regulatory applications in the United States (U.S. EPA 2005). This model has also been adopted in Ontario as the regulatory model recommended for permitting and regulatory applications (MOECC 2009).

The AERMOD modelling system was selected as the dispersion model for the NSDF Project due to its following capabilities:

- has a technical basis that is scientifically sound, and is in keeping with the current understanding of dispersion in the atmosphere;
- applies formulations that are clearly delineated and are subjected to rigorous independent scrutiny;
- makes predictions that are consistent with observations;
- is recognized by federal and provincial regulators as one suitable for use;

- evaluates the various source configurations and indicator compounds associated with the NSDF Project;
- the terrain surrounding the NSDF Project is relatively simple and can be addressed by the terrain features of the model;
- allows for the use of localised meteorological data;
- incorporates building downwash effects; and,
- long-range transport of compounds is not anticipated.

The AERMOD modelling system consists of the AERMOD dispersion model, the AERMET meteorological pre-processor and the AERMAP terrain pre-processor. The following approved dispersion model and pre-processors were used in the assessment:

- AERMOD dispersion model (v. 15181);
- AERMAP surface pre-processor (v. 11103); and,
- Building Profile Input Program (BPIP) building downwash pre-processor (v.42104).

The AERMET meteorological pre-processor was used by the MOECC to prepare a 5-year meteorological data set for the NSDF Project. The meteorological data set incorporated data from the CNL on-site station. Additional information on the meteorology is presented in Appendix 5.2-1. Details regarding the dispersion modelling, including receptor grids and source input parameters are provided in Appendix 5.2-4.

5.2.1.6.2 Application Case Results

Average and Maximum Emission Rates

In accordance with the CNSC REGDOC-2.9.1 (CNSC 2016), average and maximum emission rates have been provided for the construction and operations phases. Table 5.2.1-9 and Table 5.2.1-10 summarize the average and maximum emission rates in kilograms per day for each activity during construction, respectively. Table 5.2.1-11 and Table 5.2.1-12 summarize the average and maximum emission rates in kilograms per day for each activity during the operations phase, respectively. Vehicle exhaust and fugitive dust from unpaved roads is the largest contributor to SPM and PM_{10} during both construction and operations. Vehicle exhaust during the construction and operation of the ECM is the largest contributor of $PM_{2.5}$, NOx/NO_2, SO_2, CO, and C_3H_4O. Details of the specific emission calculation methods and resulting emissions estimates used for dispersion modelling are provided in Appendix 5.2-3.

This page intentionally left blank

Table 5.2.1-9: Summary of Average Emission Rates during the Construction Phase

NSDF Project Activity[a]	Source	Activity	Average emission rates (kg/day)											
			SPM	PM_{10}	$PM_{2.5}$	NO_x/NO_2	SO_2	CO	C_3H_4O	Hg	Pb	H_2S	C_2H_3Cl	Odour (OU/day)
—	Engineered Containment Mound	ECM cap	—	—	—	—	—	—	—	—	—	—	—	—
—		ECM passive vents	—	—	—	—	—	—	—	—	—	—	—	—
All construction activities[b]		ECM construction (material handling)	0.02	0.011	0.002	—	—	—	—	—	—	—	—	—
All construction activities[b]		ECM construction (vehicle exhaust)	3.21	3.21	3.21	101.95	0.12	19.88	0.00279	—[c]	—[c]	—	—	—
All construction activities[b]	Unpaved Roads	Vehicle exhaust and fugitive road dust	35.88	9.55	1.00	0.07	0.00	0.04	0.00002	—[c]	—[c]	—	—	—
All construction activities[b]	Stockpiles	Stockpile	3.11	1.56	0.23	—	—	—	—	—	—	—	—	—
—	Waste Water Treatment Plant	Wastewater treatment activities	—	—	—	—	—	—	—	—	—	—	—	—
—		WWTP natural gas combustion	—	—	—	—	—	—	—	—	—	—	—	—
—	Support Activities	Vehicle Decontamination Facility natural gas combustion	—	—	—	—	—	—	—	—	—	—	—	—
—		Administration Office natural gas combustion	—	—	—	—	—	—	—	—	—	—	—	—
—		Operations Support Centre natural gas combustion	—	—	—	—	—	—	—	—	—	—	—	—
—		Diesel emergency power generators	—	—	—	—	—	—	—	—	—	—	—	—

a) As described in the air quality pathway analysis in Section 5.2.1.5.2

b) Construction activities include site preparation, construction of the ECM, development of the surface water management structures, construction of the WWTP and other support facilities, and on-site road access development.

c) Hg and Pb occur as trace elements from the combustion of diesel fuel and are excluded from the diesel combustion sources emissions.

ECM = engineered containment mound; WWTP = wastewater treatment plant; kg/day = kilogram per day; SPM = suspended particulate matter; $PM_{2.5}$ = particulate matter less than 2.5 µm (microns) in diameter; PM_{10} = particulate matter less than 10 µm (microns) in diameter; NO_2 = nitrogen dioxide; SO_2 = sulphur dioxide; CO = carbon monoxide; H_2S; = hydrogen sulfide; C_2H_3Cl = vinyl chloride; Pb = lead; Hg = mercury; OU/day = Odour Unit per day.

Table 5.2.1-10: Summary of Maximum Emission Rates during the Construction Phase

NSDF Project Activity[a]	Source	Activity	Maximum emission rates (kg/day)											
			SPM	PM_{10}	$PM_{2.5}$	NO_x/NO_2	SO_2	CO	C_3H_4O	Hg	Pb	H_2S	C_2H_3Cl	Odour (OU/day)
—	Engineered Containment Mound	ECM cap	—	—	—	—	—	—	—	—	—	—	—	—
—		ECM passive vents	—	—	—	—	—	—	—	—	—	—	—	—
All construction activities[b]		ECM construction (material handling)	0.02	0.011	0.002	—	—	—		—	—	—	—	—
All construction activities[b]		ECM construction (vehicle exhaust)	6.41	6.41	6.41	203.90	0.24	39.76	0.00559	—[c]	—[c]	—	—	—
All construction activities[b]	Unpaved Roads	Vehicle exhaust and fugitive road dust	171.23	46.23	4.63	0.29	0.00	0.16	0.00005	—[c]	—[c]	—	—	—
All construction activities[b]	Stockpiles	Stockpile	3.11	1.56	0.23	—	—	—	—	—	—	—	—	—
—	Waste Water Treatment Plant	Wastewater treatment activities	—	—	—	—	—	—	—	—	—	—	—	—
—		WWTP natural gas combustion	—	—	—	—	—	—	—	—	—	—	—	—
—	Support Activities	Vehicle Decontamination Facility natural gas combustion	—	—	—	—	—	—	—	—	—	—	—	—
—		Administration Office natural gas combustion	—	—	—	—	—	—	—	—	—	—	—	—
—		Operations Support Centre natural gas combustion	—	—	—	—	—	—	—	—	—	—	—	—
—		Diesel emergency power generators	—	—	—	—	—	—	—	—	—	—	—	—

a) As described in the air quality pathway analysis in Section 5.2.1.5.2

b) Construction activities include site preparation, construction of the ECM, development of the surface water management structures, construction of the WWTP and other support facilities, and on-site road access development.

c) Hg and Pb occur as trace elements from the combustion of diesel fuel and are excluded from the diesel combustion sources emissions.

ECM = engineered containment mound; WWTP = wastewater treatment plant; kg/day = kilogram per day; SPM = suspended particulate matter; $PM_{2.5}$ = particulate matter less than 2.5 µm (microns) in diameter; PM_{10} = particulate matter less than 10 µm (microns) in diameter; NO_2 = nitrogen dioxide; SO_2 = sulphur dioxide; CO = carbon monoxide; H_2S; = hydrogen sulfide; C_2H_3Cl = vinyl chloride; Pb = lead; Hg = mercury; OU/day = Odour Unit per day.

Table 5.2.1-11: Summary of Average Emission Rates during the Operation Phase

NSDF Project Activity[a]	Source	Activity	Average emission rates (kg/day)											
			SPM	PM_{10}	$PM_{2.5}$	NO_x/NO_2	SO_2	CO	C_3H_4O	Hg	Pb	H_2S	C_2H_3Cl	Odour (OU/day)
—	Engineered Containment Mound	ECM cover	—	—	—	—	—	3.05E-04	—	1.09E-08	—	4.87E-04	3.97E-05	109
—		ECM passive vents	—	—	—	—	—	2.75E-03	—	9.84E-08	—	4.39E-03	3.57E-04	984
Staged development of the ECM disposal cells, placement of waste in the ECM, and progressive closure of disposal cells and installation of cover		ECM operation (material handling)	0.03	0.01	1.80E-03	—	—	—	—	—	—	—	—	—
Staged development of the ECM disposal cells, placement of waste in the ECM, and progressive closure of disposal cells and installation of cover		ECM operation (vehicle exhaust)	3.60	3.60	3.60	113.10	0.13	22.50	3.14E-03	—[b]	—[b]	—	—	—
On-site transportation of waste	Unpaved Roads	Vehicle exhaust and fugitive road dust	87.88	23.73	2.38	0.15	1.11E-03	0.08	2.50E-05	—[b]	—[b]	—	—	—
Staged development of the ECM disposal cells	Stockpiles	Stockpile	0.83	0.41	0.06	—	—	—	—	—	—	—	—	—
Operation of WWTP	Waste Water Treatment Plant	Wastewater treatment activities	—	—	—	—	—	—	—	—	—	—	—	31,826
Operation of WWTP		WWTP natural gas combustion	6.01E-03[c]	6.01E-03[c]	6.01E-03[c]	2.00E+00[c]	1.20E-02[c]	1.68E+00[c]	—	—[d]	1.00E-05	—	—	—
—	Support Activities	Vehicle Decontamination Facility natural gas combustion	1.28E-03[c]	1.28E-03[c]	1.28E-03[c]	4.26E-01[c]	2.56E-03[c]	3.58E-01[c]	—	—[d]	2.13E-06	—	—	—
—		Administration Office natural gas combustion	7.25E-05[c]	7.25E-05[c]	7.25E-05[c]	2.42E-02[c]	1.45E-04[c]	2.03E-02[c]	—	—[d]	1.21E-07	—	—	—
—		Operations Support Centre natural gas combustion	2.03E-04[c]	2.03E-04[c]	2.03E-04[c]	6.78E-02[c]	4.07E-04[c]	5.69E-02[c]	—	—[d]	3.39E-07	—	—	—
—		Diesel emergency power generators	—[e]	—[e]	—[e]	—[e]	—[e]	—[e]	—[e]	—[b]	—[b]	—	—	—

a) As described in the air quality pathway analysis in Section 5.2.1.5.2

b) Hg and Pb occur as trace elements from the combustion of diesel fuel and are excluded from the diesel combustion sources emissions.

c) Contaminants are presented for completeness however they have not been carried through for the dispersion modelling assessment as they were identified as negligible as identified in Table 3.

d) Hg occurs as trace element from the combustion of natural gas and is excluded from the natural gas combustion sources emissions.

e) The emergency power generator was excluded from the air quality assessment as it is used during monthly routine maintenance testing and to provide electricity during a power outage when other equipment is not in operation.

ECM = engineered containment mound; WWTP = wastewater treatment plant; kg/day = kilogram per day; SPM = suspended particulate matter; $PM_{2.5}$ = particulate matter less than 2.5 µm (microns) in diameter; PM_{10} = particulate matter less than 10 µm (microns) in diameter; NO_2 = nitrogen dioxide; SO_2 = sulphur dioxide; CO = carbon monoxide; H_2S; = hydrogen sulfide; C_2H_3Cl = vinyl chloride; Pb = lead; Hg = mercury; OU/day = Odour Unit per day.

Table 5.2.1-12: Summary of Maximum Emission Rates during the Operation Phase

NSDF Project Activity[a]	Source	Activity	Maximum emission rates (kg/day)											
			SPM	PM_{10}	$PM_{2.5}$	NO_x/NO_2	SO_2	CO	C_3H_4O	Hg	Pb	H_2S	C_2H_3Cl	Odour (OU/day)
—	Engineered Containment Mound	ECM cover	—	—	—	—	—	3.05E-04	—	1.09E-08	—	4.87E-04	3.97E-05	109
—		ECM passive vents	—	—	—	—	—	2.75E-03	—	9.84E-08	—	4.39E-03	3.57E-04	984
Staged development of the ECM disposal cells, placement of waste in the ECM, and progressive closure of disposal cells and installation of cover		ECM operation (material handling)	0.03	0.01	1.80E-03	—	—	—	—	—	—	—	—	—
Staged development of the ECM disposal cells, placement of waste in the ECM, and progressive closure of disposal cells and installation of cover		ECM operation (vehicle exhaust)	7.20	7.20	7.20	226.21	0.26	45.00	6.29E-03	—[b]	—[b]	—	—	—
On-site transportation of waste	Unpaved Roads	Vehicle exhaust and fugitive road dust	175.77	47.46	4.75	0.30	0.00	0.16	4.99E-05	—[b]	—[b]	—	—	—
Staged development of the ECM disposal cells	Stockpiles	Stockpile	0.83	0.41	0.06	—	—	—	—	—	—	—	—	—
Operation of WWTP	Waste Water Treatment Plant	Wastewater treatment activities	—	—	—	—	—	—	—	—	—	—	—	432,000
Operation of WWTP		WWTP natural gas combustion	6.01E-03[c]	6.01E-03[c]	6.01E-03[c]	2.00E+00[c]	1.20E-02[c]	1.68E+00[c]	—	—[d]	1.00E-05	—	—	—
—	Support Activities	Vehicle Decontamination Facility natural gas combustion	1.28E-03[c]	1.28E-03[c]	1.28E-03[c]	4.26E-01[c]	2.56E-03[c]	3.58E-01[c]	—	—[d]	2.13E-06	—	—	—
—		Administration Office natural gas combustion	7.25E-05[c]	7.25E-05[c]	7.25E-05[c]	2.42E-02[c]	1.45E-04[c]	2.03E-02[c]	—	—[d]	1.21E-07	—	—	—
—		Operations Support Centre natural gas combustion	2.03E-04[c]	2.03E-04[c]	2.03E-04[c]	6.78E-02[c]	4.07E-04[c]	5.69E-02[c]	—	—[d]	3.39E-07	—	—	—
—		Diesel emergency power generators	—[e]	—[e]	—[e]	—[e]	—[e]	—[e]	—[e]	—[b]	—[b]	—	—	—

a) As described in the air quality pathway analysis in Section 5.2.1.5.2

b) Hg and Pb occur as trace elements from the combustion of diesel fuel and are excluded from the diesel combustion sources emissions.

c) Contaminants are presented for completeness however they have not been carried through for the dispersion modelling assessment as they were identified as negligible as identified in Table 3.

d) Hg occurs as trace element from the combustion of natural gas and is excluded from the natural gas combustion sources emissions.

e) The emergency power generator was excluded from the air quality assessment as it is used during monthly routine maintenance testing and to provide electricity during a power outage when other equipment is not in operation.

ECM = engineered containment mound; WWTP = wastewater treatment plant; kg/day = kilogram per day; SPM = suspended particulate matter; $PM_{2.5}$ = particulate matter less than 2.5 µm (microns) in diameter; PM_{10} = particulate matter less than 10 µm (microns) in diameter; NO_2 = nitrogen dioxide; SO_2 = sulphur dioxide; CO = carbon monoxide; H_2S; = hydrogen sulfide; C_2H_3Cl = vinyl chloride; Pb = lead; Hg = mercury; OU/day = Odour Unit per day.

This page intentionally left blank

Negligible Emissions from the Project

There are many activities associated with the NSDF Project that produce emissions; however, not all activities produce emissions for any or all compounds that are relevant to the overall emissions assessment. All activities that potentially produce emissions are evaluated to identify their relevance; however, only activities that are considered to be relevant are included in the assessment.

The following lists rationale as to why certain activities and/or emissions of certain compounds are excluded from the assessment:

- the emission rates of certain compounds are minor relative to the overall emissions at the NSDF Project;
- the emissions of certain sources are known to not be relevant due to the type of operations in the assessment; and,
- the location of the source relative to the rest of the sources on-site (i.e., the source is located far away from any potential receptors).

Table 5.2.1-13 lists the activities that are not assessed and the accompanying rationale.

Table 5.2.1-13: Emission Sources and Contaminants not included in the Assessment

Activity/Compound	Rationale for Excluding from the Assessment
Natural gas combustion for WWTP process and comfort heating	NOx, CO, SO_2, SPM, PM_{10}, and $PM_{2.5}$ emissions from these sources occur seasonally (i.e., do not occur at all times during a year) and are minor compared to emissions from the mobile combustion sources. Only Pb emissions were included in the dispersion modelling.
Wastewater Treatment Plant and associated equipment (i.e., equalization tanks)	The treatment of wastewater may result in the release of hydrogen sulfide, mercaptans, chlorine and various other chemicals, to a lesser extent. With the exception of odour, the emissions from the WWTP have been excluded from the assessment as they are expected to have a negligible effect on the overall air quality.
WWTP Collection equalization pond	Potential odourous emissions from this source are minor and do not occur at all times, as the pond is used infrequently for peak flow management and WWTP maintenance.
Diesel emergency power generators	The emergency power equipment only operates periodically during monthly routine maintenance testing and for very short duration (20 minutes; rather than continuously). Additionally, the emergency power generator will only be used to supply electricity during power outage when other equipment is not operation; and therefore, is not included in the representative scenario and the modelling is meant to represent normal operations for the NSDF Project.
Diesel pumps, air compressors, and lighting equipment at all NSDF buildings	This equipment is part of miscellaneous equipment and only operates periodically and for short durations. Emissions rates from these sources are minor compared to emissions from the other diesel equipment on-site, and therefore, are not included in the representative scenarios.
Snow removal equipment	Emissions from this equipment occur seasonally and are infrequent (i.e., only during the winter following a snowfall), and therefore, are not included in the representative scenario.
Operational support activities, such as maintenance activities	Emissions from these sources are infrequent, relatively minor, and do not occur at all times compared to the other activities that are occurring regularly and/or continuously. For example, these activities may include minor emissions such as particulates and metals (e.g., welding).

Note: WWTP = wastewater treatment plant.

Predicted Modelling Concentrations

Concentrations resulting from the construction and operations phases of the NSDF Project for the air quality indicator compounds were predicted with the aid of the AERMOD dispersion model (Tables 5.2.1-9 to 5.2.1-12). The predicted concentrations at the LSA boundary for the construction and operations phases are presented in Table 5.2.1-14. The maximum predicted incremental concentration represents the incremental effect of the NSDF Project, without taking into consideration existing Base Case concentrations. The predicted concentrations for the Application Case represent the combined concentrations of the Base Case plus the incremental concentrations from the NSDF Project. Predicted concentrations for the Application Case during both construction and operations phases are below applicable air quality guidelines and/or standards.

Table 5.2.1-14: Concentrations at the Local Study Area Boundary for the Base Case and Application Case

Indicator	Averaging Period	Air Quality Guideline/ Standard (µg/m³)[(a)]	Base Case (Existing Conditions) (µg/m³)[(b)]	Maximum Predicted Incremental Concentration – Construction Phase (µg/m³)	Maximum Predicted Incremental Concentration – Operation Phase (µg/m³)	Application Case - Construction Phase (µg/m³)	Application Case - Operation Phase (µg/m³)
SPM	24-hour	120	30.95	29.90	25.61	60.85	56.56
SPM	Annual	60	14.53	4.03	3.70	18.56	18.23
PM_{10}	24-hour	50	15.48	9.56	7.72	25.04	23.20
$PM_{2.5}$	24-hour	30	7.74	2.70	1.80	10.44	9.54
$PM_{2.5}$	Annual	8.8	3.63	0.27	0.22	3.90	3.85
NO_2[(d)]	1-hour	400	31.98	139.36	100.81	171.34	132.79
NO_2	24-hour	200	28.61	63.31	42.21	91.92	70.82
NO_2	Annual	60	14.86	5.24	4.27	20.10	19.13
SO_2	1-hour	690	2.62	0.71	0.26	3.33	2.88
SO_2	24-hour	275	2.62	0.07	0.05	2.69	2.67
SO_2	Annual	55	1.05	0.01	0.00	1.06	1.05
CO	1-hour	36,200	458.10	119.16	44.54	577.26	502.64
CO	8-hour	15,700	486.73	32.59	23.99	519.32	510.72
C_3H_4O	1-hour	4.5	—	0.02	0.01	0.02	0.01
C_3H_4O	24-hour	0.4	—	0.002	0.001	0.002	0.001
Pb	24-hour	0.5	—[(c)]	—[(c)]	3.25E-06	—[(c)]	3.25E-06
Pb	30-day	0.2	—[(c)]	—[(c)]	3.37E-07	—[(c)]	3.37E-07
Hg	24-hour	2	0.0046	—[(c)]	1.64E-08	—[(c)]	0.0046
H_2S	10-min	13	—[(c)]	—[(c)]	0.01	—[(c)]	0.01
H_2S	24-hour	7	—[(c)]	—[(c)]	0.001	—[(c)]	0.001
C_2H_3Cl	24-hour	1	—[(c)]	—[(c)]	5.94E-05	—[(c)]	5.94E-05
Odour[(e)]	10-min	1	—[(c)]	—[(c)]	0.04	—[(c)]	0.04

a) Table 5.2.1-4 identifies which guideline or standard was used in the screening of effects to air quality.

b) The 90th percentile predicted existing concentrations; values for SPM and PM_{10} are calculated from the $PM_{2.5}$ as described in Section 5.2.1.

c) "—"indicates there are no predicted concentrations because there are no emissions.

d) Calculated using the Ozone Limiting Method (OLM). Refer to Section 5.2 of Appendix 5.2-4 for calculation methodology.

e) 99.5th percentile on a 10-minute averaging period, in OU/m^3.

SPM = suspended particulate matter; $PM_{2.5}$ = particulate matter less than 2.5 µm (microns) in diameter; PM_{10} = particulate matter less than 10 µm (microns) in diameter; NO_2 = nitrogen dioxide; SO_2 = sulphur dioxide; CO = carbon monoxide; C_3H_4O = acrolein H_2S; = hydrogen sulfide; C_2H_3Cl = vinyl chloride; Pb = lead; Hg = mercury; µg/m³ = microgram per cubic metre.

5.2.1.7 Prediction Confidence and Uncertainty

Potential sources of uncertainty in the assessment of air quality include:

- potential modifications associated with the exact location, physical footprint and activity level of the NSDF Project;
- the accuracy and representativeness of the activity data and emission factors used to estimate emissions;
- the accuracy and representativeness of the waste inventory;
- the accuracy and representativeness of the meteorological data used in the AERMOD model;
- the accuracy of formulations within the AERMOD dispersion modelling system;
- the representativeness of the ambient data used to represent background concentrations; and,
- the potential error associated with omitting some emission sources.

Dispersion models employ assumptions that simplify the random processes associated with atmospheric motions and turbulence. While this simplification limits the model's ability to replicate individual events, the strength of the model lies in the ability to predict overall values for a given set of meteorological conditions. The process undertaken by the U.S. EPA ensured that the model predictions can be relied on as reasonable estimate of the likely concentrations. AERMOD is based on known theory, and proven to reliably produce repeatable results (Section 5.2.1.6.1). The above uncertainties were managed using the following conservative assumptions in the emission estimation and dispersion modelling:

- Waste receipt for the maximum capacity of 1,000,000 cubic metres (m^3) was used in determining emission rates for dispersion modelling. All emission rate calculations were completed for the maximum amount of waste received during the entire life of the NSDF Project.
- The ECM was modelled as an area source. Modelling the ECM emissions as an area source assumes that emissions are being released from the entire area, however in reality emissions will only be emitted from discrete areas on the source.
- The modelling assessment includes all operations occurring simultaneously and continuous over the entire modelling period. Variable emission rates were not used for the material handling activities and vehicle traffic although these activities are planning to only occur during the daytime and weekdays.
- The influence of natural mitigation from events such as rainfall, snowfall, residual moisture, or snow cover was not considered in determining fugitive dust emission rates for all sources, except unpaved roads and grading. The modelling will likely yield higher concentrations since contaminants will be deposited from the air by dry or wet depletion and deposition processes.
- The 90th percentile observed concentration was added to maximum predicted concentrations for short-term averaging periods to account for existing background emission sources. The use of 90th percentile background concentrations is conservative in that it assumes that the maximum predicted concentration and the 90th percentile background concentration will occur at the same time, even though background concentrations greater than or equal to the 90th percentile occur only 10% of the time.

- Five years of meteorological data are used as an input to the model to provide that a full range of possible meteorological conditions is evaluated.

The parameters that were required for fugitive dust modelling from unpaved roads include the locations of the roadway segments, base elevations, effective heights of the emissions, and the initial plume size in the lateral and vertical directions. It is recognized that this modelling approach will result in higher predicted concentrations close to the roadways than actual values for the following reasons:

- There has been extensive research on the estimation of the “transportable fraction” of fugitive dust from roadways. Studies completed by the Desert Research Institute in Nevada and in the San Joaquin Valley, CA (Watson et al. 1996) showed a large (i.e., greater than 90%) decrease in dust concentration within 100 metres (m) of an unpaved road (Watson et al. 1996; Watson et al. 2000). A value of 75% reduction has been suggested beyond 50 m for unpaved roadway emissions. This value would increase at greater distances. This adjustment was not be made to the dispersion modelling concentration results.
- When the roads are wet or snow-covered, the emissions will be reduced or eliminated. AERMOD has the capacity to have a variable emission rate that could account for actual meteorological emissions; however variable emission rates were not used in this assessment for conservatism.
- The best management practices will further reduce emissions; specifically, watering was assumed to be used on unpaved roads to decrease emissions from roads and a truck-wheel wash station will be used to reduce track out.

It is assumed that the conservative emission rates, when combined with the conservative operating conditions and conservative dispersion modelling assumptions description herein, are not likely to under predict the modelled concentrations at each of the identified receptors.

5.2.1.8 Residual Effects Classification and Determination of Significance

This section classifies the residual effects from changes to measurement indicators for the Application Case and presents a determination of significance for the air quality VC.

5.2.1.8.1 Residual Effects Classification

Effects from adverse residual changes to measurement indicators were classified using a categorical scale and common words to facilitate the determination of significance. The purpose of categorical classification is to provide definitions that permit a clear, thorough and unambiguous classification of residual effects such that reviewers and readers can follow and apply the logic used in the assessment and reach the same classification for a given residual effect.

Magnitude, geographic extent and duration are the principal factors considered to predict significance. The magnitude of a residual environmental effect is determined by the change in a measurement indicator from a project interaction. Geographic extent refers to the area affected and duration is defined as the amount of time for a residual effect to be reversed. For air quality, residual effects stop almost immediately when the NSDF Project activity stops. It should be noted that reversibility refers to effects to air quality only; how effects to air quality affect other VCs are assessed in their discipline-specific sections. Other criteria, such as frequency and likelihood are used as modifiers, where applicable. Residual adverse effects were classified using the criteria and definitions outlined in Table 5.2.1-15.

Table 5.2.1-15: Assessment Criteria for Classifying Predicted Residual Adverse Effects to Air Quality

Direction	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Likelihood
Positive: Maximum concentration for an indicator compound represents a decrease from Base Case. **Negative:** Maximum concentration for an indicator compound represents an increase from Base Case. **Neutral:** No change in concentrations of an indicator compound relative to Base Case.	**Negligible:** Maximum concentration for an indicator compound is <5% of the corresponding criteria **Low:** Maximum concentration for an indicator compound is less than 50% of the corresponding criteria **Moderate:** Maximum concentration for an indicator compound is between 50% and 100% of the corresponding criteria **High:** Maximum concentration for an indicator compound is above the corresponding criteria	**Local:** Effect is limited to within the LSA **Regional:** Effect extends beyond the LSA, but is contained within the RSA **Beyond Regional:** Effect extends beyond the RSA	**Short-term:** Effects are not evident beyond the construction phase **Medium-term:** Effects are not evident beyond the operations phase **Long-term:** Effects are not evident beyond the closure and post-closure phases **Permanent**: Effects are not reversible	**Infrequent:** Effects are confined to a specific discrete period **Frequent:** Effects occur intermittently, but repeatedly, or continuous over the assessment period	**Reversible:** Change of state in environment is not permanent **Irreversible:** Change of state in the environment is permanent	**Low:** Effect is unlikely to occur **Medium:** Effect is likely to occur **High:** Effect is highly likely to occur

5.2.1.8.2 Determination of Significance

The residual effects classification of primary pathways and the associated predicted changes in measurement indicators provide the foundation for determining the significance of residual effects from the NSDF Project on air quality. Where possible and appropriate, established guidelines, thresholds and screening values were used to support the classification of the predicted amount of change in measurement indicators and associated effects on air quality. For an effect to be deemed significant the effect must be negative in direction, high in magnitude, regional in geographic extent and long term in duration. As part of the determination of significance, confidence in the assessment identified in Section 5.2.1.7 was considered for the air quality VC. Where uncertainty was high and the cumulative effect might be either significant or not significant, the assessment conservatively identified the effect as significant and provided additional follow-up actions to reduce uncertainty (Section 5.2.1.9).

The geographic extent, duration, frequency and likelihood of effect are the same for all indicator compounds for each of the Application Cases (i.e., construction and operations phases), and only the direction and magnitude varies by contaminant (Table 5.2.1-16). The predicted effects are limited to the LSA, and therefore the geographic extent of changes to all indicator compounds is local for both Application Case phases. Emissions of indicator compounds will stop at the end of the construction and operations phase; therefore the duration of effect is short-term and medium term, respectively. Criteria air contaminants will be emitted continuously or near-continuously during the construction and operations phases, and therefore the frequency of effect is frequent. The likelihood of emissions from the NSDF Project changing indicator compound concentrations for the Application Case during construction and operations is high (Table 5.2.1-16).

For the Application Case – Construction Phase, the direction is neutral for some indicator compounds as there are no emissions of this compound during this phase of the NSDF Project (i.e., SO_2, C_2H_3Cl, and odour). The magnitude of changes to indicator compound emissions are predicted to be negligible to low as the predicted concentrations are below the relevant guideline/standard. The overall residual adverse effect of the Application Case during construction on air quality is therefore determined to be not significant.

For the Application Case – Operations Phase, the direction is negative for all indicator compounds as concentrations of emissions are predicted to increase during this phase of the NSDF Project. However, the magnitude of changes to indicator compound emissions are predicted to be negligible to low as the predicted concentrations are below the relevant guideline/standard. The overall residual adverse effect of the Application Case during operations on air quality is therefore determined to be not significant.

Table 5.2.1-16: Classification of Predicted Residual Adverse Effects on Air Quality for the Application Case

Indicator Compound	Direction	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Likelihood
Application Case – Construction Phase							
SPM	Negative	Low	Local	Short-term	Frequent	Reversible	High
PM_{10}	Negative	Low	Local	Short-term	Frequent	Reversible	High
$PM_{2.5}$	Negative	Low	Local	Short-term	Frequent	Reversible	High
NO_2	Negative	Low	Local	Short-term	Frequent	Reversible	High
SO_2	Neutral	Low	Local	Medium-term	Frequent	Reversible	High
CO	Negative	Low	Local	Short-term	Frequent	Reversible	High
C_3H_4O	Negative	Low	Local	Short-term	Frequent	Reversible	High
Hg	Negative	n/a	n/a	n/a	n/a	n/a	n/a
Pb	Negative	n/a	n/a	n/a	n/a	n/a	n/a
H_2S	Negative	n/a	n/a	n/a	n/a	n/a	n/a
C_2H_3Cl	Neutral	n/a	n/a	n/a	n/a	n/a	n/a
Odour	Neutral	n/a	n/a	n/a	n/a	n/a	n/a
Application Case – Operations Phase							
SPM	Negative	Low	Local	Medium-term	Frequent	Reversible	High
PM_{10}	Negative	Low	Local	Medium-term	Frequent	Reversible	High
$PM_{2.5}$	Negative	Low	Local	Medium-term	Frequent	Reversible	High
NO_2	Negative	Low	Local	Medium-term	Frequent	Reversible	High
SO_2	Negative	Negligible	Local	Medium-term	Frequent	Reversible	High
CO	Negative	Negligible	Local	Medium-term	Frequent	Reversible	High
C_3H_4O	Negative	Negligible	Local	Medium-term	Frequent	Reversible	High
Hg	Negative	Negligible	Local	Medium-term	Frequent	Reversible	High
Pb	Negative	Negligible	Local	Medium-term	Frequent	Reversible	High
H_2S	Negative	Low	Local	Medium-term	Frequent	Reversible	High
C_2H_3Cl	Negative	Negligible	Local	Medium-term	Frequent	Reversible	High
Odour	Negative	Low	Local	Medium-term	Frequent	Reversible	High

n/a = neutral effects are not classified; SPM = suspended particulate matter; PM2.5 = particulate matter less than 2.5 µm (microns) in diameter; PM10 = particulate matter less than 10 µm (microns) in diameter; CO = carbon monoxide; NO_2 = nitrogen dioxide; SO_2 = sulphur dioxide; C_3H_4O = acrolein; CO = carbon monoxide; H_2S; = hydrogen sulfide; C_2H_3Cl = vinyl chloride; Pb = lead; Hg = mercury.

5.2.1.9 Monitoring and Follow-up

The Procedure for Management and Monitoring of Emissions [CW-509200-PRO-001] outlines the key management practices to limit effects to air quality. Implementation of CNL's Procedure for Management and Monitoring of Emissions [CW-509200-PRO-001], which includes operational control monitoring and air verification monitoring. The CRL radiological air Effluent Verification Monitoring Program (EVMP) comprises 56 monitoring points and will continue for the NSDF Project. In addition, air quality monitoring activities for the NSDF Project will be implemented (Table 5.2.1-17) and the purpose it to:

- verify effects predictions, and compare actual with predicted effects;
- confirm effectiveness of mitigation, and in doing so evaluate if alternate mitigation is required;
- provide information for use in adaptive management to address potential unforeseen effects; and,
- demonstrate compliance with regulatory requirements.

Table 5.2.1-17: Environmental Monitoring and Follow-up Programs for Air Quality

Valued Component	Project Phase and Potential Effect	Monitoring Program Objective	Conceptual Monitoring Program	Suggested Duration	Implementing Program
Air Quality	Construction activities will result in fugitive dust emissions.	■ Verify that mitigation measures are being implemented effectively. ■ Verify predictions are within air quality criteria.	■ Application of aggregate to unpaved roads – a record will be kept of the date of each application of aggregate to unpaved roads. ■ Road misting – a record will be maintained of road misting. ■ Site inspection – during periods of high dust susceptibility, regular inspections will be carried out to monitor the efficacy of dust mitigation and any potential concerns with regards to fugitive dust, and if required implementation of mitigation measures will be recommended. Environmental conditions will be recorded. ■ Particulate monitoring – Suspended particulate matter (SPM) using a high volume sampler.	Through the construction phase	Dust Management Plan to be developed and implemented for the NSDF Project.

Valued Component	Project Phase and Potential Effect	Monitoring Program Objective	Conceptual Monitoring Program	Suggested Duration	Implementing Program
Air Quality	Operations activities will result in fugitive dust emissions.	■ Verify that the following mitigation measures are being incorporated as planned, and are effective. ■ Verify predictions are within air quality criteria.	■ Application of aggregate to unpaved roads – a record will be kept of the date of each application of aggregate to unpaved roads. ■ Road misting – a record will be maintained of road misting. ■ Site inspection – during periods of high dust susceptibility, regular inspections will be carried out to monitor the efficacy of dust mitigation and any potential concerns with regards to fugitive dust, and if required implementation of mitigation measures will be recommended. Environmental conditions will be recorded. ■ Vehicle decontamination – a record will be kept of the number of waste delivery vehicles recorded thru the vehicle decontamination facility. ■ Particulate monitoring – SPM using a high volume sampler.	Based on observations and monitoring data during first year of operation, the frequency of monitoring would be re-evaluated.	Captured through the implementation of CNL's Procedure for Management and Monitoring of Emissions, which includes operational control monitoring and air verification monitoring.

5.2.1.10 Conclusions

Valued components refer to environmental features that may be affected by a project and that have been identified to be of concern by the proponent, scientists, government agencies, First Nations and Métis communities, or the public (the Agency 2014). Air quality was selected as a VC as emissions from the NSDF Project activities have the potential to alter the existing air quality regime. The assessment endpoint for the air quality assessment are performance against criteria and thresholds for protection of human health and the environment. The measurement indicators for air quality include changes in ambient concentrations of indicator compounds and dustfall deposition rates in comparison to the provincial or federal ambient air quality criteria.

Residual effects from activities that occur during the construction and operations phases have been identified as the primary linkage to potentially affect ambient air quality. During the construction and operations phases, NSDF Project activities will result in emissions associated with the operation of vehicles and equipment, as well as emissions from the decomposition of waste in the ECM. A summary of the predicted residual adverse effects for air quality, including associated mitigation, are provide in Table 5.2.1-18. Examples of mitigation practices implemented to limit predicted residual effects to air quality include:

- implementation of CNL’s Procedure for Management and Monitoring of Emissions, which includes operational control monitoring, air verification monitoring and environmental monitoring;
- development and implementation of the Dust Management Plan for the NSDF Project;
- the primary dust control method will include water spraying or misting techniques (e.g., water trucks);
- vehicles that have come into contact with contamination will need to pass through the vehicle decontamination facility; and,
- on-site vehicles and equipment engines will meet Tier 2 emission standards and be maintained in good working order.

The predicted residual effects air quality were estimated to increase because of the NSDF Project. Vehicle exhaust and fugitive dust from unpaved roads is the largest contributor to particulate matter (SPM, PM_{10}, and $PM_{2.5}$) during both the construction and operations phases. Vehicle exhaust during the construction of the ECM is the largest contributor of NO_x/NO_2 and CO. Predicted concentrations for the Application Case during both construction and operations phases are below applicable air quality guidelines and/or standards. Consequently, the residual effects from the NSDF Project on air quality was predicted to be not significant. The Procedure for Management and Monitoring of Emissions for CNL outlines the key management practices that limit air quality emissions effects, as well as the current monitoring requirements.

Table 5.2.1-18: Summary of Predicted Residual Adverse Effects for Air Quality Valued Components

Valued Components	Assessment Endpoint	Residual Adverse Effects	Project Effect Occurs in	Contributing Project Activity	Proposed Mitigation	Significance
Air Quality	Performance against criteria and thresholds for protection of human health and the environment	Construction and operation activities use vehicles and equipment that combust fuel and emit indicator compounds. These activities involve material handling, vehicles travelling on unpaved roads, and wind erosion of stockpiles that will result in fugitive dust emissions.	Construction and Operations	**Construction** ■ Site preparation ■ Construction of the ECM ■ Development of surface water management structures ■ Construction of the WWTP and other support facilities ■ On-site road and access development **Operations** ■ Staged development of disposal cells ■ On-site transportation of waste and placement of waste in the ECM ■ Progressive closure of disposal cells and installation of cover ■ Operation of the WWTP	■ Implementation of Canadian Nuclear Laboratories' (CNL) Procedure for Management and Monitoring of Emissions, which includes operational control monitoring, air verification monitoring and environmental monitoring. ■ Implementation of the Dust Management Plan developed for the NSDF Project, which includes appropriate management techniques to control dust generated by the NSDF Project. ■ On-site vehicles and equipment engines will meet Tier 2 emission standards and be maintained in good working order. ■ Limit idling of vehicles on-site. ■ Processed leachate will not be heated within the WWTP ■ There is active ventilation within the WWTP building and all emissions to air will be filtered prior to release.	Not Significant

5.2.2 Greenhouse Gases

Section 5.2.2 focuses on greenhouse gases (GHG). Greenhouse gases have the potential to affect future climate as they contribute to the greenhouse effect by absorbing infrared radiation in the atmosphere, increasing temperature and changing weather patterns.

5.2.2.1 Scope of the Assessment

The GHG assessment follows the overall environmental assessment approach and methods described in Section 5.1. The assessment is completed in the following eight primary steps:

- **Step 1 – Identify Valued Components (VCs) and define the spatial boundaries, temporal boundaries, and assessment cases** for the GHG assessment (refer to Sections 5.2.2.2 Valued Components and Section 5.2.2.3 Assessment Boundaries). The VCs, assessment endpoints, and measurement indicators used to assess NSDF Project related changes to GHG; the spatial and temporal boundaries at which the assessment occurred; and, the assessment cases considered.
- **Step 2 – Describe the existing conditions** (refer to Section 5.2.2.4 Description of the Environment). Existing conditions in the local and regional areas are described, including the combined effects of previous and existing developments (Base Case). The existing environment represents the historical and current environmental pressures that have shaped the observed patterns in the environment (i.e., natural variation).
- **Step 3 – Evaluate Project interactions and mitigation** (refer to Section 5.2.2.5 Project Interactions and Mitigation). Project components and/or activities with the potential to affect GHG are identified and mitigation developed to limit or avoid effects is presented. A pathways analysis is then used to focus further assessment on key interactions between the NSDF Project and the environment by evaluating the different effect pathways to determine if, after incorporation of mitigation, there is still potential to cause residual effects. Where effects are adequately mitigated and are not forwarded for further analysis (i.e., secondary pathways, or where mitigation will remove the pathway altogether), the reasons for concluding the assessment at this stage are articulated. Primary pathways that may lead to residual effects to GHG after incorporating mitigation are carried forward to Steps 4 for further analysis and residual effects characterization.
- **Step 4 - Present the methods and results of the residual effects analysis** (refer to Section 5.2.2.6 Residual Effects Analysis). This section outlines the methods used to predict and characterize residual effects to GHG from primary effect pathways. The analysis results are also presented including the characterization of incremental effects from the NSDF Project, as well as cumulative effects of the Project in combination with other reasonably foreseeable developments (if applicable).
- **Step 5 – Describe the level of certainty and management of uncertainty** (refer to Section 5.2.2.7 Prediction Confidence and Uncertainty). This purpose of this section is to evaluate the available literature, data, and models used for the assessment, and describe the level of certainty that can be placed on predicted residual effects. This section will also identify how the uncertainty has been managed so that the effects are not underestimated.

- **Step 6 – Classify and determine the significance of the predicted residual effects** (refer to Section 5.2.2.8 Residual Effects Classification and Determination of Significance). Residual effects predicted from primary pathways are classified using a common set of criteria: direction, magnitude, geographic extent, duration, reversibility, frequency, and likelihood. A determination of the significance of the predicted residual effects from NSDF Project for the GHG VC is made.
- **Step 7 - Identify monitoring and follow-up** required to confirm effects predictions and address uncertainty (refer to Section 5.2.2.9 Monitoring and Follow-up).
- **Step 8 - Present a consolidated summary of conclusions and outcomes of the assessment** of residual effects on air quality (refer to Section 5.2.2.10 Conclusions).

Information and areas of interest raised by the public, communities of interest, regulators, and First Nations and Métis communities during engagement that influenced the scope of the GHG assessment are summarized in Table 5.2.2-1. Other general areas of interest and questions (if any) raised during the engagement that pertain to the GHG assessment are documented in Appendix 4.0-22 Formal Public Feedback.

Table 5.2.2-1: Summary of Areas of Interest Raised During Engagement Activities that Influenced the Scope of the Greenhouse Gases Assessment

Area of Interest	How the Area of Interest Was Included in the Assessment
Will the Near Surface Disposal Facility produce methane gas?	The release of methane gas from the engineered containment mound is evaluated in the greenhouse gas assessment. Mitigation to limit the release of methane gas are discussed in Section 5.2.2.5.2 and predictions of methane gas release from the engineered containment mound are found in Section 5.2.2.6.2. The monitoring program to be implemented to verify that the measures for controlling landfill gas generated from wasted deposited in the engineered containment mound during operations and following final closure are adequate is described in Section 5.2.2.9.
Would like information on monitoring air contaminations.	The monitoring program proposed for greenhouse gas emissions is described in Section 5.2.2.9. Greenhouse gas monitoring is also captured through the implementation of CNL's Procedure for Management and Monitoring of Emissions, which includes operational control monitoring and verification monitoring.

5.2.2.2 Valued Components

Valued components refer to environmental features that may be affected by a project and that have been identified to be of concern by the proponent, scientists, government agencies, First Nations and Métis communities, or the public (the Agency 2014). Greenhouse gases was selected as a VC as there is a potential for the NSDF Project activities to release GHG emissions that could contribute incrementally to climate change (Table 5.2.2-2). The mechanism by which the Project has the potential to contribute to global climate change is by the addition of GHG emissions. Greenhouse gases refer to a group of gases that build up in the atmosphere and have the potential to contribute incrementally to climate change.

Table 5.2.2-2: Valued Components for the Greenhouse Gases Assessment

Valued Component	Rationale for Selection
Greenhouse Gases	This valued component, assessed through incremental changes in emissions of a group of gases, considers the potential of the Project to contribute to climate change.

Assessment endpoints are qualitative expressions used to assess the significance of residual effects on VCs and represent the key properties of the VC that should be protected for future generations. The assessment endpoint for GHG is comparison to provincial and national totals (Table 5.2.2-3). Measurement indicators represent properties of the environment and VCs that, when changed, could result in or contribute to an effect on an assessment endpoint. Measurement indicators also provide the primary factors for discussing the uncertainty of effects on VCs and, subsequently, are the key variables for study in follow-up and monitoring programs. The measurement indicators considered in the GHG assessment include changes in concentrations of the following indicator compounds:

- carbon dioxide (CO_2);
- methane (CH_4); and,
- nitrous oxide (N_2O).

There are no NSDF Project activities that are expected to emit sulphur hexafluoride (SF_6), perfluorocarbons (PFCs) or hydrofluorocarbons (HFCs); therefore these compounds are not included in the GHG assessment. Greenhouse gas emissions are expressed as tonnes of equivalent CO_2, calculated by multiplying the annual emissions of each indicator compound by its 100-year global warming potential (GWP). A single measure is used when evaluating effects, namely the maximum annual GHG emissions resulting from the NSDF Project activities in tonnes of carbon dioxide equivalent (CO_2e). The assessment endpoints and measurement indicators used in the GHG assessment are listed in Table 5.2.2-3.

Table 5.2.2-3: Assessment Endpoints and Measurement Indicators for the Greenhouse Gas Assessment

Valued Component	Assessment Endpoints	Measurement Indicators
Greenhouse gases	Comparison of GHG emissions to provincial and national totals	Changes in greenhouse gas emissions (CO_2, CH_4 and N_2O) compared to provincial and national GHG totals

CO_2 = carbon dioxide; CH_4 = methane; N_2O = nitrous oxide.

5.2.2.3 Assessment Boundaries

5.2.2.3.1 Spatial Boundaries

The spatial boundaries for the GHG assessment are considered to be beyond regional as the predicted residual adverse effect of GHG emissions is considered global in nature.

5.2.2.3.2 Temporal Boundaries

Temporal boundaries (i.e., project phases) establish the timeframe during which NSDF Project effects are assessed. Four project phases were identified for the NSDF Project including the construction phase, operations

phase, closure phase, and post-closure phase (refer to Section 5.2.1.1 for more details on each phase). For the purposes of the GHG assessment, only the construction and operation phases have been considered. The GHG emissions from operations include the first year after closure, which represents the year were emissions from the decomposition of the waste within the ECM are expected to be at their highest. Therefore, GHG emissions during operations phase are expected to be greater than the GHG emissions from the closure phase and the emissions from the post-closure phase are expected to be considerably less than the operations phase.

5.2.2.3.3 Assessment Cases

The assessment cases considered in the GHG assessment include the Base Case and the Application Case:

- **Base Case –** This scenario represents existing conditions and characterizes effects from previous and existing developments and activities. The Base Case reflects the effects of existing disturbances in the area, such as forestry, transportation, agricultural, mining, and residential and recreational development. For example, current effects from the existing operations and activities on the CRL property are considered part of the Base Case.
- **Application Case –** This scenario represents the effects of the Base Case combined with the predicted effects that from the NSDF Project. The Application Case was divided into the construction phase and the operations phase, and therefore, the emissions and associated effects during the construction and operations phases of the NSDF Project represent the bounding cases. Only direct GHG emissions within the SSA have been considered in this assessment (i.e., emissions outside of the Site Study Area, for example from off-site transportation of construction materials, are not included in the assessment). Direct emissions include emissions that are owned or controlled by CNL, such as fuel use and GHG emitted from the decomposition of the waste within the ECM. Indirect GHG emissions, such as electricity, are emissions that are a consequence of the CNL activities, but occur at sources owned or controlled by another entity; and therefore are excluded from the assessment.
- **Reasonably Foreseeable Development (RFD) Case** – There are no foreseeable developments expected in the region other than the decommissioning of the remaining CRL structures. No known reasonably foreseeable future developments have been identified within 10 km of the CRL site (i.e., the air quality RSA). The waste from the decommissioning of the CRL structures will be placed in the NSDF and the Application Case for the operations phase considers the transport of this waste for disposal in the ECM. Decommissioning activities will involve similar equipment used during the construction phase of the NSDF Project, and are expected to release the same GHG emissions (vehicle and equipment exhaust). Consequently, the Application Case construction phase is considered to capture the effects from the decommissioning of the CRL structures.

5.2.2.4 Description of the Environment

5.2.2.4.1 Methods

Applicable Criteria

The relevant GHG emissions criteria include the provincial and federal emission levels. These emission levels are calculated using the assessment frameworks summarized below, followed by the baseline GHG emissions levels considered for the Base Case.

Technical Guidance on Reporting Greenhouse Gas Emissions, Environment and Climate Change Canada (November 2015)

The *Technical Guidance on Reporting Greenhouse Gas Emissions* (ECCC 2015) provides direction in determining if facilities are required to submit a GHG report to Environment and Climate Change Canada (ECCC) under the Greenhouse Gas Reporting Program (GHGRP), an overview of the reporting process, as well as technical information related to GHG emissions estimations, including identifying GHG emission sources subject to reporting (ECCC 2015). The GHGRP falls under the *Canadian Environmental Protection Act* (CEPA). The GHGRP Guideline references GHG estimation methodologies from the United Nations Framework Convention on Climate Change (UNFCCC) and was developed by the Intergovernmental Panel on Climate Change (IPCC). The GHGRP Guideline states that “no specific estimation methods are prescribed” and that facilities should choose estimation methods that are most appropriate for their particular industry, but are consistent with the guidelines adopted by the UNFCCC for preparing GHG inventories. The reporting threshold for the GHGRP is 50,000 tonnes of carbon dioxide equivalent (CO_2e).

Guideline for Greenhouse Gas Emissions Reporting, Ontario MOECC (2015)

Ontario Regulation (O.Reg.) 452/09 governs the documentation and reporting of GHG emissions in Ontario. The *Guideline for Greenhouse Gas Emissions Reporting* (MOECC 2015; the O.Reg. 452/09 Guideline) provides the emission estimation methods that are required to be used under this reporting regulation. The emissions generated at the NSDF Project are defined by the O.Reg. 452/09 Guideline GHG emission estimation method ON.20 (General Stationary Combustion) for natural gas and diesel combustion and ON.280 (Mobile Equipment Operation) for the mobile equipment. The emissions generated from the ECM final cover are not covered under O.Reg. 452/09. The reporting threshold for O.Reg. 452/09 is 10,000 tonnes of CO_2e as of January 1, 2016.

Baseline GHG Emissions Data

Existing GHG emissions are not measured; however, they are routinely estimated. For the purposes of this GHG assessment, federal and provincial reported GHG data, as well as CNL data, is used to describe the GHG emissions. The following sources of information were used to characterize the existing GHG emissions:

- ECCC National Inventory Report 1990-2014: Greenhouse Gas Sources and Sinks in Canada (ECCC 2016);
- MOECC greenhouse gas emissions reporting by facility from the 2014 reporting year (MOECC 2014); and,
- Annual Safety Report Effluent Verification Monitoring at Chalk River Laboratories in 2015 (CNL 2016).

5.2.2.4.2 Base Case Results

The latest available federal and provincial reported GHG data was used to describe the background GHG emissions. The latest available federal and provincial data is from the 2014 reporting year (ECCC 2016). There are no large GHG emitters within 100 km of the NSDF Project with the exception of the CRL main campus (MOECC 2014). The latest data provided by CNL, indicated that the CNL main campus contributed 38,598 tonnes of CO_2e in 2015 (CNL 2016). Total federal, provincial, and CRL campus GHG emissions are provided in Table 5.2.2-4.

Table 5.2.2-4: Baseline Greenhouse Gas Emissions

Source	GHG Emissions (tonnes CO_2e)
Canada-wide 2014 GHG Emissions Total[a]	732,000,000
Ontario-wide 2014 GHG Emissions Total[a]	170,000,000
CRL Main Campus 2015 GHG Emissions[b]	38,598

a) National Inventory Report 1990-2014: Greenhouse Gas Sources and Sinks in Canada (ECCC 2016).
b) 2015 Effluent Verification Monitoring Report (CNL 2016).

5.2.2.5 Project Interactions and Mitigation

5.2.2.5.1 Methods

This section describes the process by which interactions between NSDF Project components and activities and GHG were identified and evaluated. Potential effect pathways are identified and mitigation developed to eliminate and/or reduce effects is presented. A pathways analysis is then used to focus the assessment on key interactions between the NSDF Project and the environment by evaluating the different effect pathways to determine if, after incorporation of mitigation, there is still potential to cause residual effects. Where effects will be adequately mitigated and are not forwarded for further analysis (i.e., secondary pathways, or where mitigation will remove the pathway altogether), the reasons for concluding the assessment at this stage are articulated. Primary pathways that may lead to residual effects after incorporation of mitigation are further characterized in subsequent subsections of the assessment (i.e., Section 5.2.2.6). As such the 'Project Interactions and Mitigations' section helps to focus the remainder of the assessment on those interactions (effects pathways) likely to result in residual adverse effects.

The first part of the analysis was to identify the potential effects pathways for all stages of the NSDF Project. The next step in the analysis was the development of environmental design features and mitigation practices that could be incorporated into the NSDF Project to eliminate and/or reduce changes to GHG emissions. Environmental design features included design elements, environmental best practices, and management policies and procedures. Environmental design features and mitigation were developed through an iterative process between the engineering and environmental teams, combined with input from project-specific or regional engagement with other interested parties. The design features and/or mitigation were considered for their effectiveness for implementation and maintenance, and their appropriateness within the context of the identified effect pathways.

After incorporation of mitigation, potential pathways were evaluated into the following categories using scientific knowledge, logic, experience with similar developments, and the effectiveness of environmental design features and mitigation:

- **No pathway –** pathway is removed by environmental design features or mitigation such that the NSDF Project would not be expected to result in a measurable environmental change to concentrations of indicator compounds relative to Base Case values, and therefore would have no residual effects to GHG.
- **Secondary pathway –** the pathway could result in a measurable minor change to concentrations of indicator compounds, but would have a negligible residual effect on GHG relative to Base Case and/or guideline values and is not expected to contribute cumulatively to other NSDF Project effects or to the effects of other past, present or reasonably foreseeable developments to cause a significant effect.

- **Primary pathway –** the pathway is likely to result in an environmental change to concentrations of indicator compounds relative to the Base Case and/or guideline values that could contribute to residual effects to GHG.

Environmental design features and mitigation that have been or could be incorporated into the NSDF Project to eliminate and/or reduce adverse effects to GHG were considered. Potential pathways that were completely removed due to implementation of environmental design or mitigation were not assessed further. Pathways that were assessed to be secondary and demonstrated to have a negligible residual effect to GHG through simple qualitative or semi-quantitative evaluation of the pathway were also not advanced for further assessment. Primary pathways were carried forward for more detailed quantitative and qualitative effects analysis to characterize the residual effects of the NSDF Project on GHG (see Section 5.2.2.6).

5.2.2.5.2 Results

Pathways through which all stages of the NSDF Project may interact with and result in changes to GHG emissions is provided in Table 5.2.2-5. The GHG emissions were estimated by taking into consideration the mitigation that were considered to be integral to the design and implementation of the NSDF Project activities. These mitigation, which are considered to be typical and consistent with best practices are presented in Table 5.2.2-5.

Table 5.2.2-5: Pathways Analysis for Greenhouse Gas Emissions Valued Components

Project Activity	Effects Pathways	Management Practices and Mitigation Actions	Pathway Assessment
Construction ■ Site preparation ■ Construction of the ECM ■ Development of surface water management structures ■ Construction of the WWTP and other support facilities ■ On-site road and access development	■ Construction activities use vehicles and equipment that combust fuel and emit GHGs. These activities involve material handling and vehicles travelling on roads. ■ Additionally, there are GHG emissions associated with land clearing for the project. One-time emissions will be presented over the life-time of the project.	■ Implementation of CNL's Procedure for Management and Monitoring of Emissions, which includes operational control monitoring and verification monitoring. ■ On-site vehicles and equipment engines will be maintained in good working order. ■ Limit idling of vehicles on-site.	Primary pathway
Operations ■ Staged development of disposal cells ■ On-site transportation of waste and placement of waste in the ECM ■ Progressive closure of disposal cells and installation of cover ■ Operation of the WWTP	■ Most activity and material handling occurs during this stage. Vehicles and equipment combust fuel and emit GHGs. These activities involve material handling with vehicles travelling on roads. The disposal cell emits GHG emissions from the decomposition of waste. The WWTP will be fuelled by Natural Gas. Additionally, there is a loss of carbon sink as a result of the cleared land for the NSDF Project.	■ Implementation of CNL's Procedure for Management and Monitoring of Emissions, which includes operational control monitoring and verification monitoring. ■ On-site vehicles and equipment engines will be maintained in good working order. ■ Limit idling of vehicles on-site.	Primary pathway

Table 5.2.2-5: Pathways Analysis for Greenhouse Gas Emissions Valued Components

Project Activity	Effects Pathways	Management Practices and Mitigation Actions	Pathway Assessment
Operations and Post-closure ■ Placement of waste in the ECM	GHG emissions from the decomposition of waste.	Installation of the final disposal cell cover will reduce release of emissions from the ECM.	Primary pathway

5.2.2.6 Residual Effects Analysis

5.2.2.6.1 Methods

Residual effects of the Project are those effects that remain after implementation of all mitigation. The assessment of effects of the Project on the GHG involves two steps, namely the calculation of emission rates and use of dispersion modelling to predict the resulting concentrations of GHG emissions. These steps are described below.

Identification of emission sources was completed by defining an inventory boundary, which frames the GHG emission sources that are included in the assessment for the NSDF Project. The inventory boundary is based on the GHGRP; and therefore, stationary fuel combustion emissions, on-site mobile emissions, and emissions from waste have been included in this GHG assessment of effects. Additionally, there is a loss of carbon sink as a result of the cleared land for the NSDF Project. Table 5.2.2-6 outlines the GHG inventory boundaries of the provincial and federal programs and presents the source categories included in the GHG assessment.

Table 5.2.2-6: Sources Categories included in the Greenhouse Gas Assessment

Source Category	O.Reg.452/09	GHGRP	GHG Assessment
On-site stationary fuel combustion sources	Y	Y	Y
On-site stationary fuel combustion for generators	N(a)	Y	Y
On-site mobile fuel combustion sources	Y(b)	Y	Y
ECM Cover (emissions from waste)	N	Y	Y
Land clearing	N	N	Y
WWTP and associated equipment (i.e., equalization tanks)	N	Y	Y

a) On-site generators are used for emergency purposes and are less than 10 megawatts, therefore are exempt from GHG reporting under O.Reg.452/09 (MOECC 2015).

b) Reporting mobile fuel combustion sources is currently optional under O.Reg.452/09.

Y = yes; N = no; ECM = engineered containment mound; GHG = greenhouse gases; GHGRP = Greenhouse Gas Reporting Guideline.

The emission estimation methods follow guidance in the Ontario MOECC Publication entitled *Guideline for Greenhouse Gas Emissions Reporting* (MOECC 2015), as set out under O.Reg. 452/09 under the *Environmental Protection Act*, as well as the ISO 14064-1 standard entitled *Specification with Guidance at the Organizational Level for Quantification and Reporting of Greenhouse Gas Emissions and Removals* (ISO 2006). Additional alternative methods, such as LandGEM (U.S. EPA 2005) were also used in the assessment to estimate emissions from the decomposition of waste within the landfill and IPCC guidelines were used to calculate greenhouse gas emissions from land clearing. Details of the specific GHG emission source identification, calculation methods, and sample calculations are provided in Appendix 5.2-3.

5.2.2.6.2 Application Case Results

Emission Rates

Table 5.2.2-7 and Table 5.2.2-8 summarizes the annual emission rates in tonnes per year for each activity at the NSDF Project for the construction and operations phases, respectively. The GWP used to calculate GHG emission in CO_2e correspond to the provincial O.Reg.452/09 GWPs. Details of the specific emission calculation methods, GWPs, and resulting emissions are provided in Appendix 5.2-3.

Table 5.2.2-7: Summary of Annual Greenhouse Gas Emissions during the Construction Phase

NSDF Project Activity	Source	Source Description	Annual GHG Emissions (tonnes/year)			Annual Total (tonnes/ year)[a]
			CO_2	CH_4	N_2O	CO_2e
Construction of the ECM, development of surface water management structures, construction of the WWTP and other support facilities, and on-site road and access development	Mobile Combustion (road & non-road vehicles)	Vehicle exhaust	6,530	0.3	1	6,841
Site Preparation	Land Clearing	One-time loss of carbon stored in biomass	160	—	—	160
		Loss of carbon sink potential	337	—	—	337
—	Support Activities	Stationary Fuel Combustion	—	—	—	—
—		Diesel emergency power generators[b]	—	—	—	—

a) Calculated using provincial GWPs

b) Compounds from this activity were considered to be negligible in comparison to the other activities occurring on-site (Refer to Table 5.2.2.9 for rationale).

"–"Not included in this assessment in the construction phase; CO_2 = carbon dioxide; CH_4 = methane; N_2O = nitrous oxide; CO_2e = carbon dioxide equivalent; GHG = greenhouse gases; ECM = engineered containment mound; WWTP = wastewater treatment plant.

Table 5.2.2-8: Summary of Annual Greenhouse Gas Emissions during the Operation Phase

NSDF Project Activity	Source	Source Description	Annual GHG Emissions (tonnes/year)			Annual Total (tonnes/ year)[(a)]
			CO_2	CH_4	N_2O	CO_2e
ECM (decomposition of waste)	Engineered Containment Mound	ECM cover (decomposition of waste emissions)	36	13	—	312
Operation of the WWTP	Stationary Fuel Combustion	Stationary Fuel Combustion	1,071	0.02	0.02	1,078
Staged development of disposal cells, on-site transportation of waste and placement of the waste in the ECM, progressive closure of disposal cells and installation of cover	Mobile Combustion (road & non-road vehicles)	Vehicle exhaust	6,706	0.3	1	7,026
Operations	Cleared Land	Loss of carbon sink potential	337	—	—	337
—	Support Activities	Diesel emergency power generators[(b)]	—	—	—	—

a) Calculated using provincial GWPs
b) Compounds from this activity were considered to be negligible in comparison to the other activities occurring on-site. See Table 5.2.2.9.
"—" not included in the assessment; = CO_2 = carbon dioxide; CH_4 = methane; N_2O = nitrous oxide; CO_2e = carbon dioxide equivalent; GHG = greenhouse gases; ECM = engineered containment mound; WWTP = wastewater treatment plant.

Negligible Emissions from the NSDF Project

There are many activities associated with the NSDF Project that produce GHG emissions; however, not all activities produce emissions for any or all compounds that are relevant to the overall emissions assessment. All activities that potentially produce emissions were evaluated to assess their relevance; however, only activities that were considered to be relevant were included in the assessment. The following lists rationale as to why certain activities and/or emissions of certain compounds are excluded from the assessment:

- the emission rates of certain compounds are minor relative to the overall emissions at the NSDF Project;
- the emissions of certain sources are known to not be relevant due to the type of operations in the assessment; and,
- the location of the source relative to the rest of the sources on-site (i.e., the source is located far away from any potential receptors).

Table 5.2.2.-9 lists the activities that were not assessed and the accompanying rationale.

Table 5.2.2-9: GHG Emission Sources and Contaminants Not Included in the Assessment

Activity/Compound	Rationale for Excluding from the Assessment
WWTP and associated equipment (i.e., equalization tanks)	The process of treatment of wastewater may result in a minor release of greenhouse gases. These emissions have been excluded from the assessment as they are negligible in comparison to the other GHG emissions from the NSDF Project. At approximately, 29 tonnes CO_2eq per year, GHG emissions from the WWTP process are less than 1% of the total GHG emissions and therefore have not been carried through the assessment..
Diesel emergency power generators	The emergency diesel generators only operates periodically during monthly routine maintenance testing and for very short duration (20 minutes) (rather than continuously). Additionally, the emergency power generator will only be used to supply electricity during power outage when other equipment is not operation, and therefore, is not included in the representative scenario. These emissions have been excluded from the assessment as they are expected to be negligible in comparison to the other GHG emissions from the NSDF Project relative to other present sources.
Diesel pumps, air compressors, and lighting equipment at all NSDF buildings	This equipment is part of miscellaneous equipment and only operates periodically and for short durations. Emissions rates from these sources are minor compared to emissions from the other diesel equipment on-site, and therefore, are not included in the representative scenarios.
Snow removal equipment	Emissions from this equipment occur seasonally and are infrequent (i.e., only during the winter following a snowfall), and therefore, are not included in the representative scenario. These emissions have been excluded from the assessment as they are expected to be negligible in comparison to the other GHG emissions from the NSDF Project relative to other present sources.

GHG = greenhouse gases; WWTP = wastewater treatment plant; <= less than;% = percent.

GHG Results

Table 5.2.2-10 summarizes the annual overall emissions in tonnes of CO_2e for the NSDF Project construction and operations phase, respectively. Greenhouse gas emissions by source is presented in Tables 5.2.2-7 and 5.2.2-8. Since both construction and operations phase GHG emissions represent less than 0.005% of the provincial total and less than 0.001% of the Canada-wide total, a comparison to the global GHG emissions total was not completed as GHG emissions from the NSDF Project represent a negligible fraction of global GHG emissions.

Table 5.2.2-10: Comparison of Greenhouse Gas Emissions from the NSDF Project to Ontario and Canadian Emission Totals

Source	Construction GHG Emissions (CO_2e tonnes/year)	Operation GHG Emissions (CO_2e tonnes/year)
NSDF Project GHG Emissions	7,338	8,752
Comparison to Canada-wide Total	0.001%	0.001%
Comparison to Ontario Total	0.004%	0.005%
Canada-wide GHG Emissions (2014)	**732,000,000**	
Ontario-wide GHG Emissions (2014)	**170,000,000**	

GHG = greenhouse gases; CO_2e = carbon dioxide equivalent; % = percent.

5.2.2.7 Prediction Confidence and Uncertainty

For the assessment of GHGs, the main sources of error are the accuracy of the activity data and hours of operation used to estimate emissions to the NSDF and the omission of some emission sources. These uncertainties were managed using conservative assumptions in the emission estimation, including:

- maximum handling and operating capacities were used in determining emission rates;
- all equipment on-site was assumed to operate concurrently; and,
- with respect to the GHG emissions and production levels used to calculate emission intensity factors, the information was derived either from the federal and provincial GHG reporting websites or from recent environmental assessments.

Sources not included in the assessment contribute less than 1% to the total GHG emissions and the Ontario regulation dictates that materiality threshold is set to 5%. Therefore, the emissions from these sources do not constitute a material error and are within the conservatism assumed in the assessment.

5.2.2.8 Residual Effects Classification and Determination of Significance

This section classifies the residual effects from changes to measurement indicators for the Application Case and presents a determination of significance for the GHG VC. The results from the GHG assessment were compared to the relevant residual effects assessment criteria to evaluate the significance of the residual adverse effects.

5.2.2.8.1 Residual Effects Classification

Effects from adverse residual changes to measurement indicators were classified using a categorical scale and common words to facilitate the determination of significance. The purpose of categorical classification is to provide definitions that permit a clear, thorough and unambiguous classification of residual effects such that reviewers and readers can follow and apply the logic used in the assessment and reach the same classification for a given residual effect.

Magnitude, geographic extent and duration are the principal factors considered to predict significance. The magnitude of a residual environmental effect is determined by the change in a measurement indicator from a project interaction. Geographic extent refers to the area affected and duration is defined as the amount of time for a residual effect to be reversed. For GHG, residual effects are not evident beyond the closure and post closure phases. Other criteria, such as frequency and likelihood are used as modifiers, where applicable. Residual adverse effects were classified using the criteria and definitions outlined in Table 5.2.2-11.

Table 5.2.2-11: Assessment Criteria for Classifying Predicted Residual Adverse Effects to Greenhouse Gases

Direction	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Likelihood
Positive: predicted GHG emissions represents a decrease from Base Case. **Negative:** predicted GHG emissions represents an increase from Base Case. **Neutral:** No change predicted GHG emissions relative to Base Case.	**Negligible:** <0.1% of the provincial emission levels, or by <0.01% of the federal emission level **Low:** >0.1% but <1% of the provincial emission levels, or by <0.01% of the federal emission levels **Moderate:** >1% compared to provincial totals, or by >0.1% compared to national totals. **High:** >5% compared to provincial totals, or by >1% compared to national totals	Beyond Regional: Effects extends beyond the RSA	**Short-term:** Effects are not evident beyond the construction phase **Medium-term:** Effects are not evident beyond the operations phase **Long-term:** Effects are not evident beyond the closure and post-closure phases **Permanent**: Effects are not reversible	**Infrequent:** Effects are confined to a specific discrete period **Frequent:** Effects occur intermittently, but repeatedly, or continuous over the assessment period	**Reversible:** Change of state in environment is not permanent **Irreversible:** Change of state in the environment is permanent	**Low:** Effect is unlikely to occur **Medium:** Effect is likely to occur **High:** Effect is highly likely to occur

5.2.2.8.2 Determination of Significance

The residual effects classification of primary pathways and the associated predicted changes in measurement indicators provide the foundation for determining the significance of residual effects from the NSDF Project on GHG. Where possible and appropriate, established guidelines, thresholds and screening values were used to support the classification of the predicted amount of change in measurement indicators and associated effects on GHG. For an effect to be deemed significant the effect must be negative in direction, high in magnitude, beyond regional in geographic extent and long-term in duration. As part of the determination of significance, confidence in the assessment identified in Section 5.2.2.7 was considered for the GHG VC. Where uncertainty was high and the cumulative effect might be either significant or not significant, the assessment conservatively identified the effect as significant and provided additional follow-up actions to reduce uncertainty (5.2.2.9).

The predicted residual adverse effect of GHG emissions is considered global in nature, and therefore the geographic extent was rated as beyond regional. Predicted effects of GHG emissions from the NSDF Project are anticipated to be reversible within the temporal boundary of the assessment and would occur continuously during operations (Table 5.2.2-12). The magnitude of the effects is rated negligible, as the change in GHG emissions due to the NSDF Project are estimated to be less than a 0.005% increase in total provincial GHG emissions and a 0.001% increase in total national GHG emissions. Consequently, the overall residual adverse effect of the Application Case during the construction and operations phases on GHG are determined to be not significant.

Table 5.2.2-12: Classification of Predicted Residual Adverse Effects on Greenhouse Gases for the Application Case

Direction	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Likelihood
Application Case – Construction Phase						
Negative	Negligible	Beyond regional	Short-term	Frequent	Reversible	High
Application Case – Operations Phase						
Negative	Negligible	Beyond regional	Long-term	Frequent	Reversible	High

5.2.2.9 Monitoring and Follow-up

The Procedure for Management and Monitoring of Emissions [CW-509200-PRO-001] (CNL 2013) outlines the key management practices to limit GHG emissions. Implementation of CNL's Procedure for Management and Monitoring of Emissions, which includes operational control monitoring and emissions verification monitoring. The CRL radiological air Effluent Verification Monitoring Program (EVMP) comprises 56 monitoring points and will continue for the NSDF Project. In addition, GHG emissions monitoring activities for the NSDF Project will be implemented (Table 5.2.2-13) and the purpose is to:

- verify effects predictions, and compare actual with predicted effects;
- confirm effectiveness of mitigation, and in doing so evaluate if alternate mitigation is required;
- provide information for use in adaptive management to address potential unforeseen effects; and,
- demonstrate compliance with regulatory requirements.

Table 5.2.2-13: Monitoring and Follow-up Programs for Greenhouse Gas Emissions

Valued Component	Project Phase and Potential Effect	Monitoring Program Objective	Conceptual Monitoring Program	Suggested Duration	Implementing Program
Greenhouse gases	GHG emissions from the decomposition of waste during operations and closure.	■ Verify that the measures for controlling landfill gas generated from wasted deposited in the ECM during operations and following final closure are adequate ■ Verify that methane emission rates used in the assessment are reasonable and conservative.	■ Monitoring for methane will be performed using handheld portable combustible gas meter detectors. ■ A passive landfill gas venting system will be constructed contemporaneously with installation of the ECM final cover system. ■ The LFG monitoring probes will also be installed around the perimeter of the ECM to detect evidence of potential LFG migration away from the ECM.	Periodic monitoring during operations and for a specific period of time during closure phase (during which the frequency may be progressively reduced and possibly ultimately eliminated if no evidence of LFG migration from the ECM is detected)	Landfill Gas Monitoring Program to be developed and implemented for the NSDF Project.
	Construction and Operations activities will result in increased greenhouse gas emissions.	Verify that GHG emission rates used in the assessment are reasonable, but conservative. Monitoring results will be used for GHG reporting requirements.	Fuel Usage – a record will be kept of the fuel usage related to the NSDF Project.	Annual estimations and GHG reporting, as required	Captured through the implementation of CNL's Procedure for Management and Monitoring of Emissions, which includes operational control monitoring and verification monitoring.

5.2.2.10 Conclusions

Valued components refer to environmental features that may be affected by a project and that have been identified to be of concern by the proponent, scientists, government agencies, First Nations and Métis communities, or the public (the Agency 2014). Greenhouse gases was selected as a VC as there is a potential for the NSDF Project activities to release GHG emissions that could contribute incrementally to climate change. The assessment endpoint for the GHG assessment is comparison to provincial and national totals. The measurement indicator for GHG include changes in emissions of CO_2e to provincial and national GHG totals.

Residual effects from activities that occur during the construction and operations phase have been identified as the primary linkage to potentially affect GHG emissions. During the construction and operations phases, NSDF Project activities will result in GHG emissions associated with the land clearing, operation of vehicles and equipment, as well as emissions from the decomposition of waste in the ECM. A summary of the predicted residual adverse effects for GHGs, including associated mitigation, are provide in Table 5.2.2-14. Examples of mitigation practices implemented to limit predicted residual effects to GHGs include:

- Implementation of CNL's Procedure for Management and Monitoring of Emissions, which includes operational control monitoring and verification monitoring;
- on-site vehicles and equipment engines will be maintained in good working order; and,
- limit idling of vehicles and equipment on-site.

The predicted residual effects to GHG emissions were estimated to increase because of the NSDF Project. The change is estimated to be less than a 0.005% increase in total provincial GHG emissions and a 0.001% increase in total national GHG emissions. Consequently, the residual effects from the NSDF Project on GHGs was determined to be not significant. The Procedure for Management and Monitoring of Emissions for CNL [CW-509200-PRO-001] outlines the key management practices that limit GHG emissions effects, as well as the current monitoring requirements.

Table 5.2.2-14: Summary of Predicted Residual Adverse Effects for Greenhouse Gas Emissions Valued Component

Valued Component	Assessment Endpoint	Residual Adverse Effects	Project Effect Occurs in	Contributing Project Activity	Proposed Mitigation	Significance
Greenhouse gases	Comparison to provincial and national totals	GHG emissions from the decomposition of waste.	Operations and Post-closure	■ Placement of waste in the ECM ■ Progressive closure of disposal cells and installation of cover	Installation of the final disposal cell cover will reduce release of emissions from the ECM.	Not Significant
Greenhouse gases	Comparison to provincial and national totals	Construction and Operations activities will result in increased greenhouse gas emissions.	Construction and Operations	**Construction** ■ Site preparation ■ Construction of the ECM ■ Development of surface water management structures ■ Construction of the WWTP and other support facilities ■ On-site road and access development **Operations** ■ Staged development of disposal cells ■ On-site transportation of waste and placement of waste in the ECM ■ Progressive closure of disposal cells and installation of cover ■ Operation of the WWTP	■ Implementation of CNL's Procedure for Management and Monitoring of Emissions, which includes operational control monitoring and verification monitoring. ■ On-site vehicles and equipment engines will be maintained in good working order. ■ Limit idling of vehicles on-site.	Not Significant

5.3 Geological and Hydrogeological Environment

Section 5.3 of the Environmental Impact Statement (EIS) for the Canadian Nuclear Laboratories (CNL) Near Surface Disposal Facility (NSDF) Project seeks to understand and characterize potential residual effects of the NSDF Project and other past, present and reasonably foreseeable developments on the physical aspects of the environment. Section 5.3.1 focuses on geology and Section 5.3.2 focuses on hydrogeology (groundwater).

5.3.1 Geology

5.3.1.1 Scope of the Assessment

The Canadian Nuclear Safety Commission's (CNSC's) Environmental Impact Statement Generic Guidelines (CNSC 2016) defined geology as including bedrock, soils and geomorphology. The geology assessment follows the overall environmental assessment approach and methods described in Section 5.1. The assessment is completed in the following key steps:

- **Step 1 – Identify Valued Components (VCs) and define the spatial boundaries, temporal boundaries and assessment cases** for the geology assessment (refer to Section 5.3.1.2 Valued Components and Section 5.3.1.3 Assessment Boundaries). The VCs and measurement indicators used to assess NSDF Project-related changes to geology; the spatial and temporal boundaries at which the assessment occurred; and, the assessment cases considered are described.
- **Step 2 – Describe the existing conditions** (refer to Section 5.3.1.4 Description of the Environment). Existing conditions in the local and regional areas are described, including the combined effects of previous and existing developments (Base Case). The existing environment represents the historical and current environmental pressures that have shaped the observed patterns in the environment (i.e., natural variation).
- **Step 3 – Evaluate Project interactions and mitigation** (refer to Section 5.3.1.5 Project Interactions and Mitigation). Project components and/or activities with the potential to affect geology are identified and mitigation developed to limit or avoid effects is presented. A pathways analysis is then used to focus further assessment on key interactions between the NSDF Project and the environment by evaluating the different effect pathways to determine if, after incorporation of mitigation, there is still potential to cause residual effects. Where effects are adequately mitigated and are not forwarded for further analysis (i.e., secondary pathways, or where mitigation will remove the pathway altogether), the reasons for concluding the assessment at this stage are articulated. Primary pathways were not identified for geology; therefore no residual effects are carried forward for further analysis and characterization.
- **Step 4 – Identify monitoring and follow-up** required to confirm effects predictions and address uncertainty (refer to Section 5.3.1.6 Monitoring and Follow-up).
- **Step 5– Present a consolidated summary of conclusions and outcomes of the assessment** of residual effects on geology (refer to Section 5.3.1.7 Conclusions).

It is important to note that the following environmental assessment steps outlined in Section 5.1 were not required as there were no primary pathways identified in the geology assessment:

- present the methods and results of the residual effects analysis;
- describe the level of certainty and management of uncertainty; and,
- classify and determine the significance of the predicted residual effects.

This section also describes how the input from engagement influenced the scope of the geology assessment. To date no areas of interest have been raised by the public, communities of interest, regulators, and First Nations and Métis communities during engagement activities specific to geology.

5.3.1.2 Valued Components

Valued components refer to environmental features that may be affected by a project and that have been identified to be of concern by the proponent, scientists, government agencies, First Nation and Métis peoples, or the public (Canadian Environmental Assessment Agency [the Agency] 2014). Geology, which includes bedrock, soils and geomorphology, is recognized as an important component of the environment that may be affected by the NSDF Project and changes to geology could, in turn, lead to effects on other VCs selected for assessment. For example, changes to the characteristics of geology, such as soil quality and quantity, have an influence on the local and regional diversity, contributing to the abundance and distribution of plants and animals on the landscape. Subsequently, changes to these characteristics by NSDF Project activities could affect terrestrial and aquatic ecosystem structure and function (Table 5.3.1-1).

Acknowledging that changes to geology are considered to be important aspects of the natural and human environment, geology is referred to as an intermediate component (i.e., it does not have an assessment endpoint). Changes to intermediate component VCs must be understood to facilitate assessment of project interactions. The geology assessment, therefore, is analyzed for incremental and cumulative (if applicable) changes in the relevant measurement indicators associated with geology (Table 5.3.1-2). The assessment of geology focused on predicting changes in the concentrations of selected non-radiological substances; radiological parameters are considered in Section 5.7 Ambient Radioactivity. The changes are characterized in terms of magnitude, duration and geographic extent, but are not classified using rankings for effects criteria. The geology assessment also does not include the assessment of the significance of these changes; rather, results of the analysis of changes in measurement indicators for geology are provided to other disciplines for inclusion in their assessment (Table 5.3.1-2).

Table 5.3.1-1: Valued Components for Geology Assessment

Valued Component	Rationale for Selection
Geology	Characteristics of geology, such as soil quality and quantity, bedrock and geomorphology, are important components that interact with other VCs (e.g., hydrogeology, hydrology and surface water quality) and if changed by NSDF Project activities could affect terrestrial and aquatic biodiversity.

Table 5.3.1-2: Measurement Indicators for the Geology Assessment

Valued Component	Measurement Indicators	Discipline Assessments where Effects on Geology are Considered
Geology	■ Bedrock ■ Soil quality, quantity and distribution ■ Geomorphology	■ Section 5.3.2 Hydrogeology ■ Section 5.4.2 Surface Water Quality ■ Section 5.5 Aquatic Biodiversity ■ Section 5.6 Terrestrial Biodiversity ■ Section 5.9 Land and Resource Use

5.3.1.3 Assessment Boundaries

5.3.1.3.1 Spatial Boundaries

The spatial boundaries selected for the geology assessment were chosen because they permit description of existing conditions in sufficient detail to enable potential project-VC interactions and effects to be identified, understood, and assessed, including understanding and assessing the contribution of the NSDF Project to cumulative effects. The spatial boundaries selected for the geology assessment are these same as those identified for hydrogeology and are presented in Figure 5.3.1-1 and described below:

- **Site Study Area (SSA):** The SSA is the NSDF Project footprint (i.e., where Project activities would be undertaken including the NSDF Project's proposed facilities, buildings and infrastructure).
- **Local Study Area (LSA):** The LSA is defined as the area within which there is potential for measurable changes to measurement indicators resulting from the proposed NSDF Project activities. The LSA includes the SSA and is bounded by Perch Lake and Perch Creek and adjacent wetlands to be consistent with the LSA of the other aquatic disciplines (e.g., hydrology, surface water quality).
- **Regional Study Area (RSA):** The RSA is defined as the area within which the potential effects of the NSDF Project may interact with the effects of other existing or reasonably foreseeable projects. The RSA for geology is determined by the spatial extent of the Perch Creek watershed, and includes the Perch Lake and Perch Creek basins to be consistent with the other aquatic disciplines.

5.3.1.3.2 Temporal Boundaries

Temporal boundaries (i.e., Project phases) establish the timeframe during which NSDF Project effects are assessed. The temporal boundary represents the timeframe during which project activities are actively occurring, and considers the duration of predicted residual effects. The duration of an effect is defined as the amount of time between the start and end of a Project activity or stressor (which is related to the project phases) plus the time required for the residual effect to be reversed. In some cases, a residual effect may be irreversible within the temporal boundaries of the Project or if the effects were predicted to last so far into the future that they could not be predicted with any level of certainty (e.g., residual effect lasts for thousands of years). The following phases were identified for the NSDF Project:

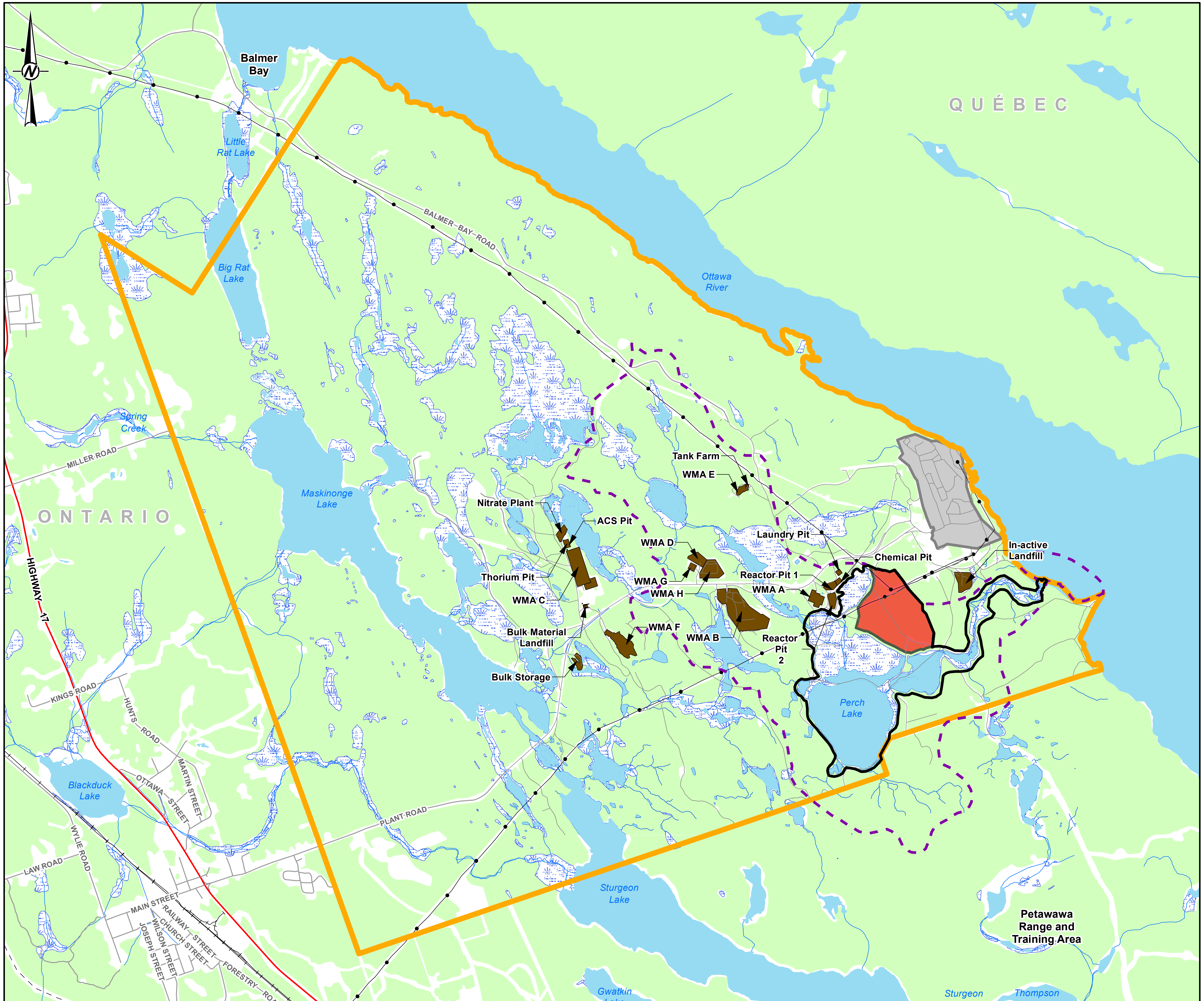
- **Construction Phase**: includes site preparation and all activities associated with the construction of the NSDF, up until operation commences with the delivery of waste. This phase includes installing the necessary supporting and/or ancillary facilities and infrastructure to facilitate NSDF operation, inactive commissioning and systems testing, and receipt of radioactive and mixed waste. Construction activities are expected to take place from 2018 to 2020.

- **Operations Phase**: includes all activities associated with the landfilling of waste receipt, waste placement, water management, wastewater treatment plant operations, vehicle movements into and from the NSDF Project site, and maintenance activities. Operations activities are expected to last approximately 50 years (i.e., 2020 to 2070).

- **Closure Phase:** includes activities necessary to complete the installation of the final cover and implementation of long-term monitoring. Closure activities are expected to start in 2070 and continue through to 2100, after which the NSDF Project will transfer into the post-closure phase.

- **Post-closure Phase:** has two discrete periods: Institutional Control and post-Institutional Control. The Institutional Control period includes implementation of both active and passive control throughout 2100 to 2400 (i.e., 300 years). During Institutional Control, groundwater monitoring and groundwater quality management will continue to demonstrate compliance with the safety case assumptions. Post-institutional Control occurs after year 2400 and continues indefinitely.

The temporal boundaries for the geology assessment consider all NSDF Project phases, from construction through to post-closure.



LEGEND

- HIGHWAY
- ROAD
- RAILWAY
- HYDRO LINE
- NATURAL GAS PIPELINE
- RIVER/STREAM
- WATERBODY
- WETLAND
- WOODED AREA
- SITE STUDY AREA (NDSF PROJECT SITE)
- CRL MAIN CAMPUS
- CRL PROPERTY
- WASTE MANAGEMENT AREA (WMA)[1]
- LOCAL STUDY AREA
- REGIONAL STUDY AREA

1 0 1
1:35,000 KILOMETERS

NOTE(S)
1. LIQUID DISPOSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.

REFERENCE(S)
1. BASEDATA ONTARIO MNRF 2016, CANVEC 2016, AND CNL 2016
2. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
3. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18N

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
SPATIAL BOUNDARIES SELECTED FOR THE GEOLOGY AND HYDROGEOLOGY ASSESSMENT

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	MM
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.3.1-1

This page left intentionally blank

5.3.1.3.3 Assessment Cases

The assessment cases considered in the geology assessment include the Base Case and Application Case:

- **Base Case –** This scenario represents existing conditions and characterizes combined effects from previous and existing developments and activities. The Base Case reflects the effects of existing disturbances, such as forestry, transportation, agricultural, mining and residential and recreational development. Current effects from the existing Chalk River Laboratories (CRL) facilities and operations, for example, are considered part of the Base Case.
- **Application Case –** This scenario represents predictions of the effects of the Base Case combined with the effects that may result from the NSDF Project. The Application Case considers potential effects from the NSDF Project during construction through to the closure and post-closure phase.
- **The Reasonably Foreseeable Developments (RFD) Case** – This scenario represents predictions of the cumulative effects of the Application Case, which includes the Base Case, plus projects that are currently under application review or that have officially entered a regulatory application process, and are therefore, considered reasonably foreseeable. New support infrastructure and research and development facilities will be located within existing disturbed areas on the CRL property (i.e., no disturbance to Greenfield areas). As such, potential effects from these activities are not expected to spatially overlap with potential effects to geology from the NSDF Project. The end-state plan for the CRL site will be to return lands disturbed by site activities to a condition that is physically stable, and safe in keeping with the land use and landscape of the day. Therefore, decommissioning and environmental restoration activities are anticipated to positively affect geology. Because RFDs will either have no spatial overlap or are likely to positively affect the geology, an RFD Case is not presented as part of this assessment..

5.3.1.4 Description of the Environment

5.3.1.4.1 Methods

Baseline geology data were collected from the review of selected geological literature (Catto et al. 1982; Chapman and Putman 1984; Raven Beck Environmental Ltd. 1994, King and Killey, 1994, and CNL 2016a) along with geological mapping produced by the Ontario Geological Survey (OGS). This information was supplemented for the SSA and LSA using reports and stratigraphic boundary points (i.e., contact elevations between geological surfaces) provided by CNL, and recent borehole drilling completed by Golder (2016) and AMEC (2016 and 2017). The stratigraphic boundary points, overburden thickness data and LiDAR topographic data provided by CNL were supplemented with the information contained in the borehole logs presented by Golder (2016) and AMEC (2016 and 2017) to develop isopach maps for the NSDF Project Site. The stratigraphic boundary points were screened to remove duplicate points and elevations were corrected using LiDAR data, where necessary. The data were then contoured using Golden Software's Surfer package to generate isopach maps of the thickness of each stratigraphic unit. Where surfaces were found to spatially overlap, they were corrected by shifting the underlying layers downward, with ground surface topography and total overburden thickness maintained. These isopach maps are described in greater detail in the following sections.

A desktop study was completed to identify the soils baseline conditions in the LSA. Information for the characterization of soils baseline conditions obtained from *The Canadian System of Soil Classification* (SCWG 1998), *The Ecosystems of Ontario, Part 1: Ecozones and Ecoregions* (Crins et al. 2009) and *The Soil Survey of Renfrew County* (Gillespie et al. 1964). Soil mapping involved the correlation of vegetation mapping to

soil substrate units. The primary soil characteristics used to group soil substrates into map units included parent material and terrain (slope and surface expression). Map units (soil polygons) were created after considering relationships between map resources, vegetation mapping, and Google Earth satellite imagery.

5.3.1.4.2 Results

5.3.1.4.2.1 Regional Geological Conditions

The CRL property is located within the Central Gneiss belt of the Grenville Structural Province of the Canadian Shield. Bedrock in the area consists of highly altered gneissic rock and felsic igneous rock (upper amphibolite to granulite grade metamorphism under dynamic ductile conditions during the Grenville Orogeny) of late Precambrian-early Paleozoic age (Figure 5.3.1-2). Structurally, the CRL property is located within the Ottawa-Bonnechere Graben or rift valley, which trends from northwest to southeast from Lake Nipissing to the St. Lawrence River occupying a 60 kilometre (km) wide by 70 km long area. The Ottawa River occupies the eastern bounding fault of the rift valley, with the CRL property located on the western edge of the river. Secondary faulting (also oriented northwest to southeast) has a considerable effect on surface drainage and bedrock topography (CNL 2016b) in the vicinity of the NSDF Project Site. Historical glaciations have generated a knobby bedrock surface (CNL 2016b), which outcrops in several locations in the region.

Bedrock in the area consists of highly altered gneissic rock and felsic igneous rock (upper amphibolite to granulite grade metamorphism under dynamic ductile conditions during the Grenville Orogeny) of late Precambrian-early Paleozoic age. Bedrock at the CRL Properties has been grouped into 3 main assemblages as shown on Figure 5.3.1-2 (from CNL 2016a). The bedrock within the Perch Lake basin and the NSDF Project Site has been mapped as quartz monzonitic, monzonitic and monzodioritic gneisses of Assemblage B. Assemblage C (composed of granitic, granodioritic and leucodioritic gneisses) has been mapped at the bedrock surface under the eastern portion of the NSDF Project site, while a mafic dyke has been mapped near the north-west corner of the NSDF Project site. Transitions between these relatively low permeability rock types are not expected to be significant to this assessment.

The regional surficial geology of the CRL property is shown on Figure 5.3.1-3 (from King and Killey, 1994). A widespread, but thin deposit of glacial till, overlies the bedrock in most areas where overburden is present (Catto et al. 1982). Following the last glacial retreat, the early post-glacial Ottawa River covered most of the CRL property and deposited fluvial sands and silts throughout the region. These fluvial deposits filled the depressions in the bedrock and glacial till surfaces. A brief period of Aeolian reworking of the fluvial sands into dune and sheet deposits occurred as the Ottawa River dropped to its current level and location. Recent sediment accumulation has been in the form of organic deposits in the low-lying and wetland areas of the region. The thickness of the unconsolidated sediments is variable as a result of the variable bedrock topography and the historical location of the Ottawa River. In general, the sediments are thickest towards the centre of the rift valley and thinnest to the west and east towards the bounding faults. As shown on Figure 5.3.1-3, surficial geology within the low lying areas of the Perch Lake Basin is predominately composed of recent organic soils. Sand and glacial till are present at surface near topographic highs, such as the NSDF Project site.

5.3.1.4.2.2 Local and NSDF Project Site Geological Conditions

The local geological conditions in the following subsection describe the lower portion of the Perch Lake Basin, and the NSDF Project site on the basis of previous investigations of the waste management areas, and recent drilling at the site.

Topography

Ground surface elevations range from a low of approximately 156 metres above sea level (masl) within the low-lying and relatively flat terrain bordering the north side of Perch Lake, to a high of 197 masl along the crest of the ridge to the east of East Mattawa Road that separates the Perch Lake and Ottawa River drainage basins. Topography and local drainage features are shown on Figure 5.3.1-4. The NSDF Project Site is located in the central portion of the lower Perch Lake Basin. Topographic evidence suggests that a former branch of the Ottawa River followed a chain of lakes, the largest of which is Maskinonge Lake, that bisect the western part of the CRL property boundary.

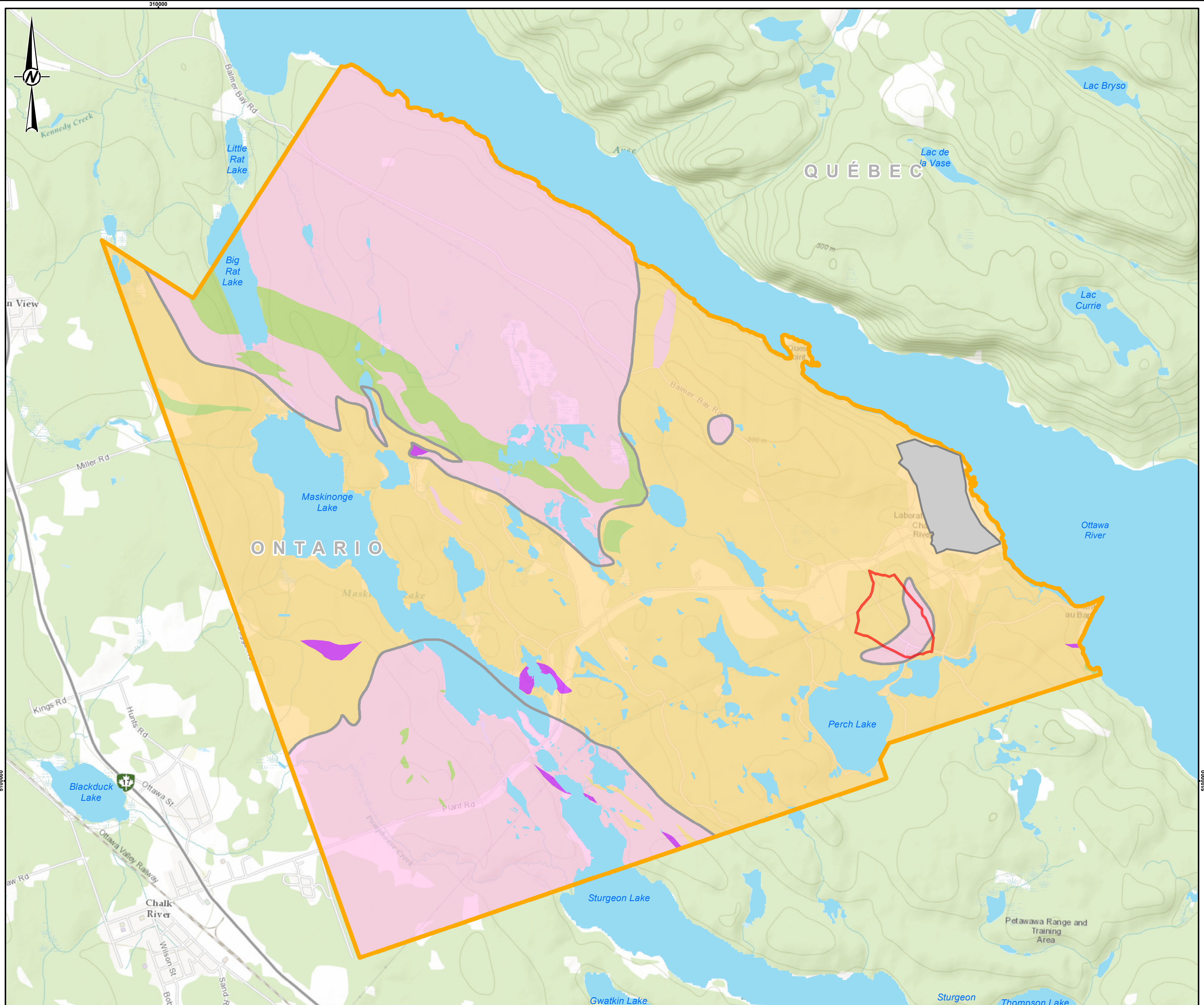
Bedrock Topography and Geology

A bedrock topography map was generated for the NSDF Project Site using stratigraphic data (Figure 5.3.1-5). The bedrock topography is dominated by the ridge that delineates the eastern boundary of the Perch Lake Basin and the depression or valley that runs from the northwest corner of Waste Management Area A, to the south east towards Perch Creek. The bedrock ridge reaches an elevation of approximately 192 masl and dips to the northwest and southeast, to an elevation of 165 masl at Plant Road and 155 masl at Perch Creek. The bedrock valley is comprised of a western portion that slopes irregularly from north to south and a southern portion that slopes irregularly from east to west. These two portions meet just north of where Main Stream discharges to Perch Lake. Bedrock in that area is at an elevation of 120 masl. The northwestern portion of the NSDF Project Site is underlain by a spur from the bedrock valley, at an elevation of 170 masl. The ridge that delineates the western boundary of the Perch Lake Basin is shown reaching an elevation of 175 masl at the limit of the map on Figure 5.3.1-5.

Two main fracture or faulting zones are present in the CRL property: the Mattawa Fault, which lies below the Ottawa River and consists of the northeast boundary of the property, and; the Maskinonge Lake lineament in the southwest area of the property. Within the Perch Lake basin a moderate probable fracture zone extends from approximately east to west through the upper portion of the basin (Raven Beck 1994). Bedrock within the Perch Lake Basin and surroundings is primarily composed of quartz monzonitic, monzonitic and monzodioritic gneisses with some occurrence of granitic-granodioritic, and leucodioritic gneisses (CNL 2016a).

Recent investigations by AMEC (2017) included the advancement of 5 boreholes to depths of up to 12.5 m below the top of the bedrock surface. Borehole logs included in AMEC (2017) indicate that the upper several metres of bedrock consist of a pink gneiss, with the exception of borehole W8, in which gneiss, monzonite, and diorite were logged. This transition in rock types in the eastern portion of the NSDF Project site appears to be consistent with the mapping shown on Figure 5.3.1-2.

This page left intentionally blank



LEGEND

- WATERBODY
- NSDF PROJECT SITE
- CRL MAIN CAMPUS
- CRL PROPERTY
- LITHOLOGICAL ASSEMBLAGES

PRE-GRENVILLE OROGENY

- DIORITIC AND AMPHIBOLITIC GNEISS
- GRANITIC, GRANODIORITIC AND LEUCODIORITIC GNEISS
- METAGABBRO AND METABASITE
- QUARTZ MONZONITIC, MONZONITIC AND MONZODIORITIC GNEISS

1 0 1
1:35,000 KILOMETRES

REFERENCE(S)

1. BASEMAP:SOURCES: ESRI, HERE, DELORME, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), SWISSTOPO, MAPMYINDIA, © OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY.
2. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
3. BEDROCK GEOLOGY: CNL. 2016A. GEOLOGIC WASTE MANAGEMENT FACILITY DESCRIPTIVE GEOSPHERE SITE MODEL REPORT: PHASE 1, 361101-10260-REPT-005, CANADIAN NUCLEAR LABORATORIES.
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18N

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
REGIONAL BEDROCK GEOLOGY

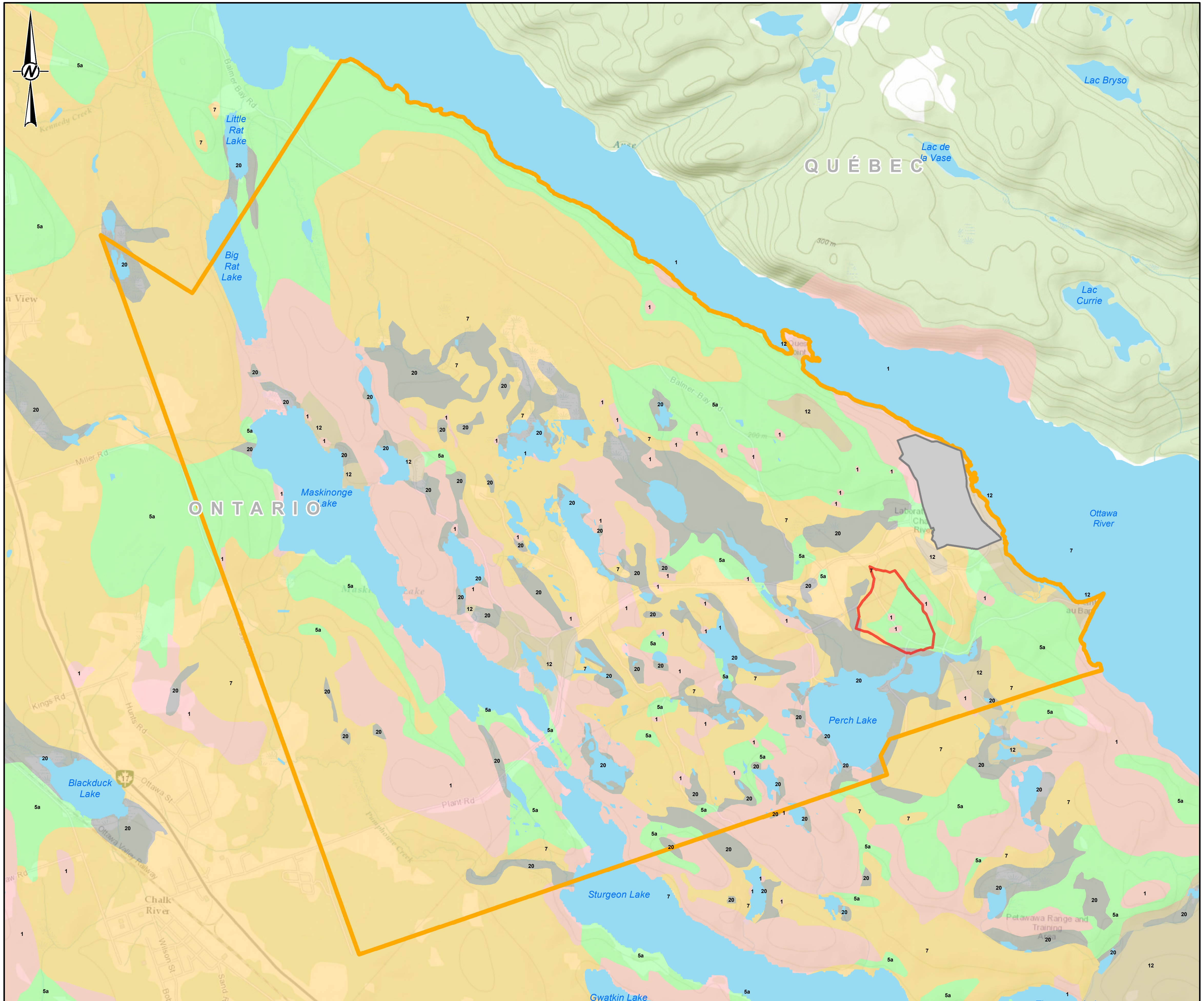
CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	MB
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.3.1-2

S:\Clients\Canadian_Nuclear_Laboratories\NSDF\99_PROJ\1547525_NSDF_EIS\40_PROD\0009_EIS_Section_5\Section_5.3_Geology_Hydrogeology\1547525-0009-CH-0002.mxd

This page left intentionally blank



LEGEND

- WATERBODY
- NSDF PROJECT SITE
- CRL MAIN CAMPUS
- CRL PROPERTY

SURFICIAL GEOLOGY

- 1: PRECAMBRIAN BEDROCK
- 5A: GLACIAL TILL
- 7: FLUVIAL AND AEOLIAN SANDS
- 12: SAND AND GRAVEL DEPOSITS
- 20: ORGANIC DEPOSITS

1 0 1
1:35,000 KILOMETRES

REFERENCE(S)

1. BASEMAP:SOURCES: ESRI, HERE, DELORME, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), SWISSTOPO, MAPMYINDIA, © OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
2. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
3. SURFICIAL GEOLOGY OF ONTARIO OBTAINED FROM ONTARIO GEOLOGICAL SURVEY (OGS) AND MINISTRY OF NORTHERN DEVELOPMENT MINES(MNDM), JUNE 2010
4. KING, K.J., AND R.W.D. KILLEY. 1994. QUATERNARY GEOLOGY OF THE AECL CHALK RIVER LABORATORIES PROPERTY: A REVIEW. STF TECH. BIB. NO. 345, SITTING TASK FORCE, LOW-LEVEL RADIOACTIVE WASTE MANAGEMENT.
5. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18N

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
REGIONAL SURFICIAL GEOLOGY

CONSULTANT
Golder Associates

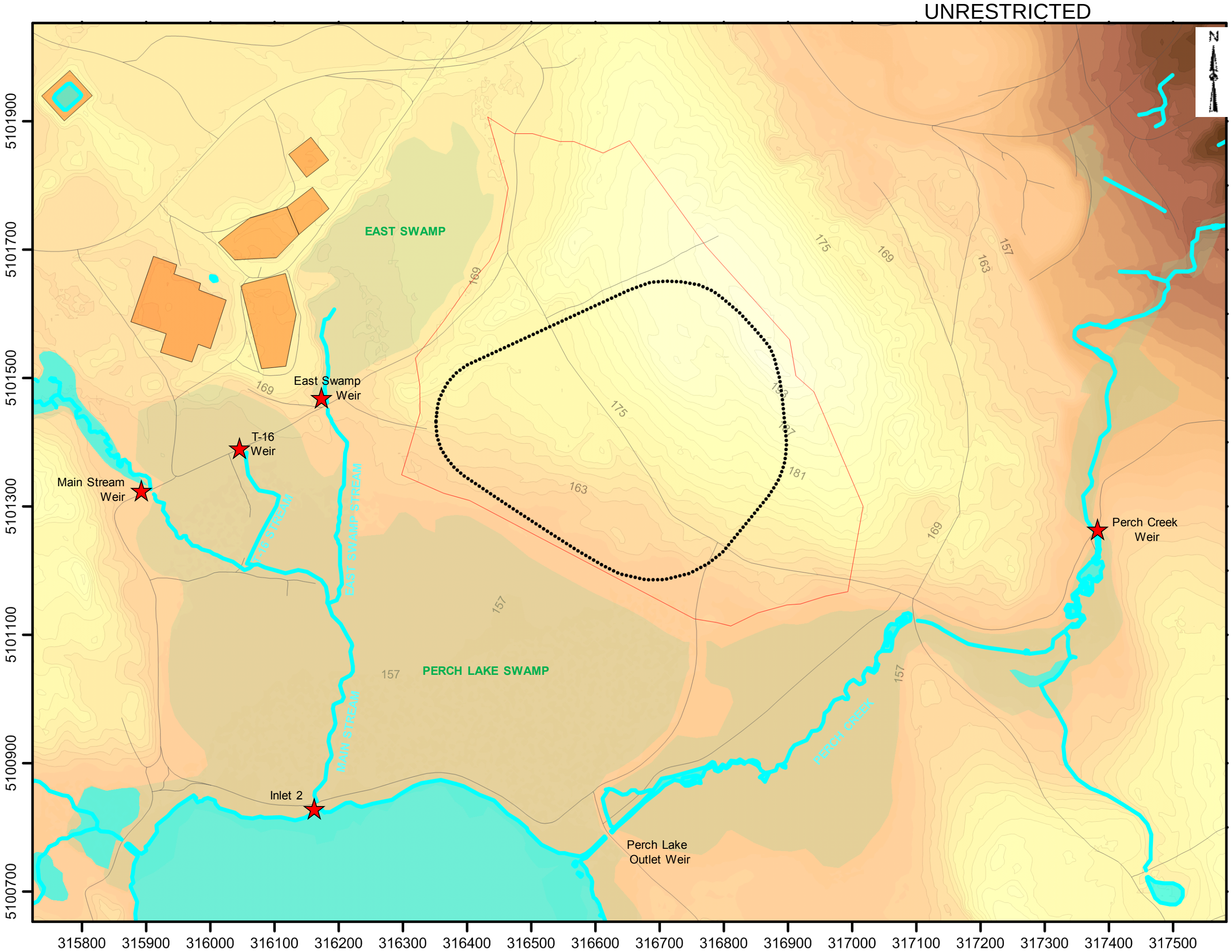
YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	MB
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.3.1-3

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm

S:\Clients\Canadian_Nuclear_Laboratories\NSDF\99_PROJ\1547525_NSDF_EIS\40_PROD\0009_EIS_Section_5\Section_5.3_Geology_Hydrogeology\1547525-0009-CH-0003.mxd

This page left intentionally blank



LEGEND
- NSDF Project Site Boundary
- Roads
- ECM Location
- Stream
- Waterbody
- Wetland
- Waste Management Area
- Weir Location

NOT TO SCALE

REFERENCE(S)
1. PERCH LAKE SUB-BASINS OBTAINED FROM E. ROBERTSON & P.J. BARRY (1985) THE WATER AND ENERGY BALANCES OF PERCH LAKE (1969–1980), ATMOSPHERE-OCEAN, 23:3, 238-253, DOI: 10.1080/07055900.1985.96492270)

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

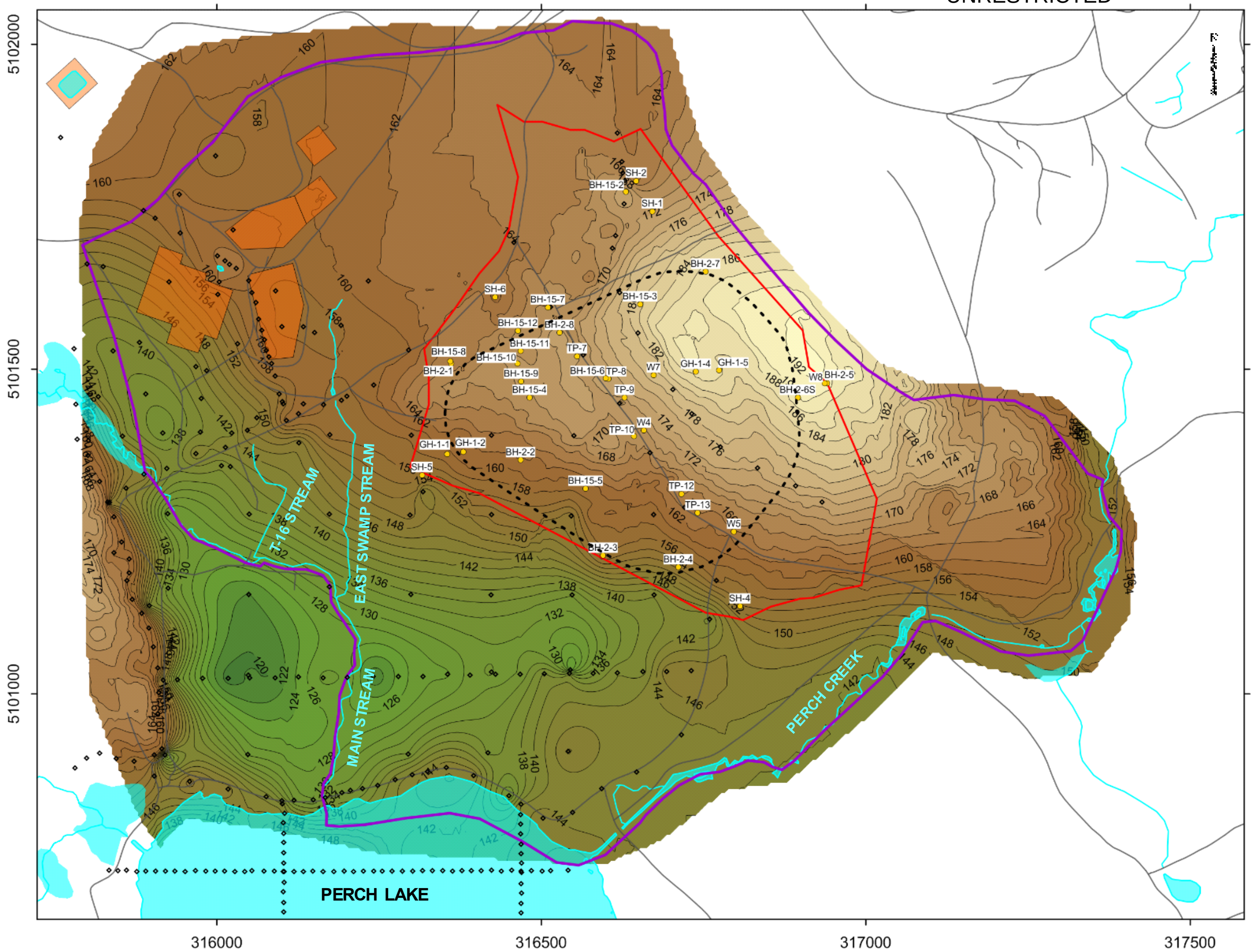
TITLE
TOPOGRAPHY AND DRAINAGE FOR THE NEAR SURFACE DISPOSAL FACILITY PROJECT SITE

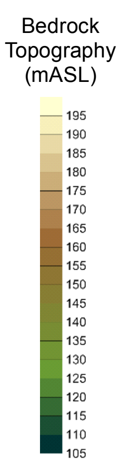
CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	NFB/MIB
PREPARED	SO/JR
REVIEWED	JL
APPROVED	GVA

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0011	0.0	5.3.1-4

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm





LEGEND

- Model Boundary
- ECM Location
- Roads
- NSDF Project Site
- Stream
- Waterbody
- Waste Management Area
- ◇ Geological Surface Data Point
- NSDF Project Data Point
- -128- Elevation Contours Lines (m asl)

NOT TO SCALE

REFERENCE(S)
1. PERCH LAKE SUB-BASINS OBTAINED FROM E. ROBERTSON & P.J. BARRY (1985) THE WATER AND ENERGY BALANCES OF PERCH LAKE (1969–1980), ATMOSPHERE-OCEAN, 23:3, 238-253, DOI: 10.1080/07055900.1985.96492270)

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
BEDROCK TOPOGRAPHY FOR THE NEAR SURFACE DISPOSAL FACILITY PROJECT SITE

CONSULTANT
Golder Associates

YYYY-MM-DD	2016-09-14
DESIGNED	NFB/MIB
PREPARED	SO/JR
REVIEWED	JL
APPROVED	GVA

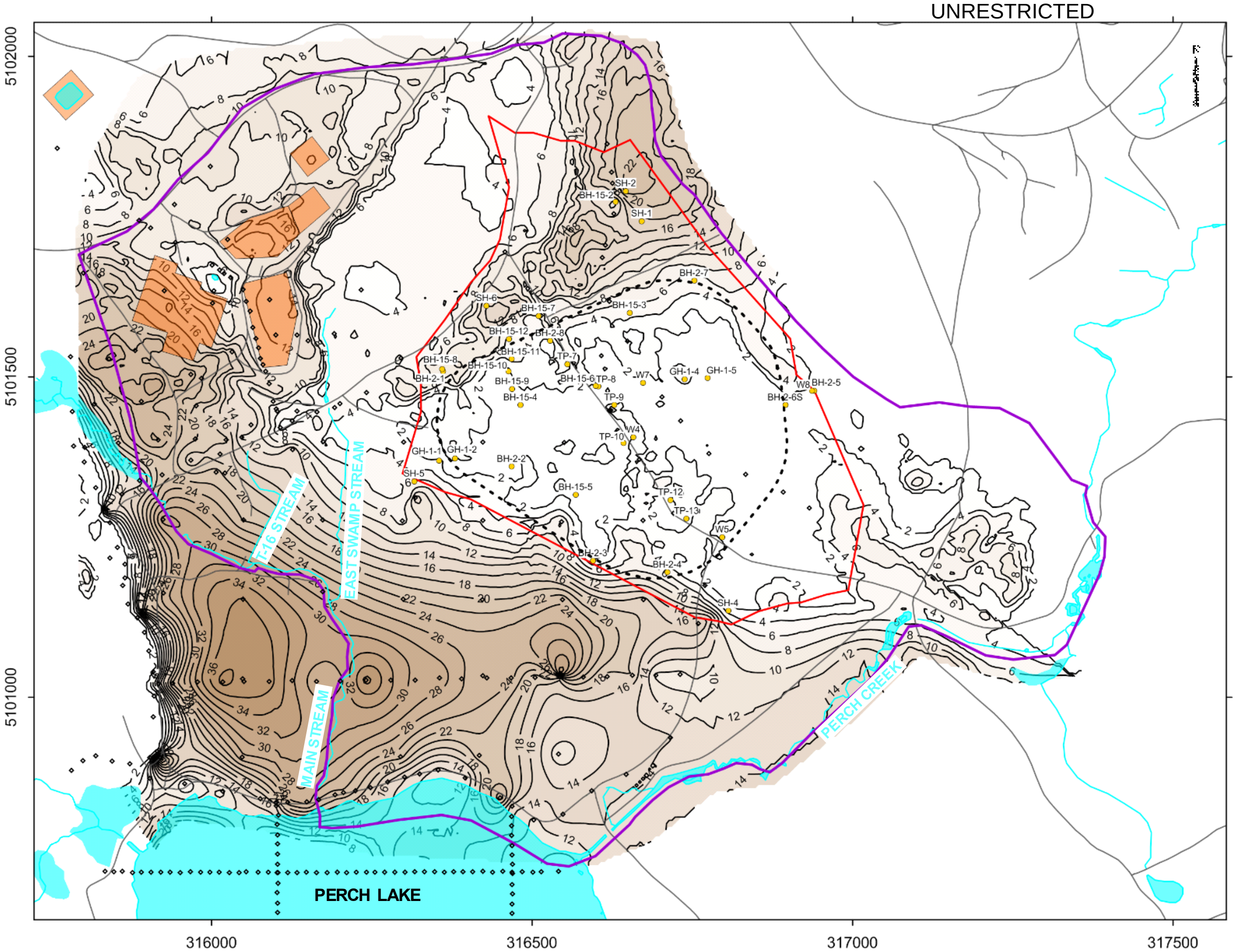
PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0011	0.0	5.3.1-5

Overburden Geology

The overburden geology at the NSDF Project site consists primarily of fine sands, underlain locally by glacial till. The sands are interpreted to be the result of aeolian reworking of precursor fluvial sands and silts laid down in the late Pleistocene/early Holocene period by an early phase of the Ottawa River. Unconsolidated glacial and post-glacial deposits in the Perch Lake Basin (which includes the LSA and NSDF Project Site) have been subdivided into six main units:

- glacial till;
- basal sand and gravel;
- clayey silt;
- middle sand;
- interstratified silt and sand; and,
- upper sand.

More recent organic deposits are also present in the Basin, but are not considered substantial hydrostratigraphic units. The total thickness of the unconsolidated deposits is shown by an isopach map on Figure 5.3.1-6. The thickness of the unconsolidated sediments is generally lowest on the eastern bedrock ridge (in the vicinity of the NSDF Project Site). The thickness of these sediments increases to the west and is highest in the bedrock valley, reaching over 36 metres (m) in the bedrock low. Within the area of the NSDF Project site unconsolidated deposits are locally thicker in the area to the north and east , reaching over 22 thick at the northern terminus of the bedrock ridge (Figure 5.3.1-6). Elsewhere on the CRL Property, overburden thickness ranges from 0 m (i.e., no overburden) to greater than 25 m, being greatest in topographic lows (Raven Beck Environmental Ltd. 1994). The sedimentary geology in the Perch Lake Basin is illustrated in cross-section on Figure 5.3.1-7.



Overburden Thickness (m)

40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0

LEGEND

- Model Boundary
- ECM Location
- Roads
- NSDF Project Site
- Stream
- Waterbody
- Waste Management Area
- Geological Surface Data Point
- NSDF Project Data Point
- Overburden Thickness Contour Lines (m)

NOT TO SCALE

REFERENCE(S)
1. PERCH LAKE SUB-BASINS OBTAINED FROM E. ROBERTSON & P.J. BARRY (1985) THE WATER AND ENERGY BALANCES OF PERCH LAKE (1969–1980), ATMOSPHERE-OCEAN, 23:3, 238-253, DOI: 10.1080/07055900.1985.96492270)

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
ISOPACH MAP – AREAL EXTENT AND THICKNESS OF UNCONSOLIDATED DEPOSITS FOR THE NSDF PROJECT SITE

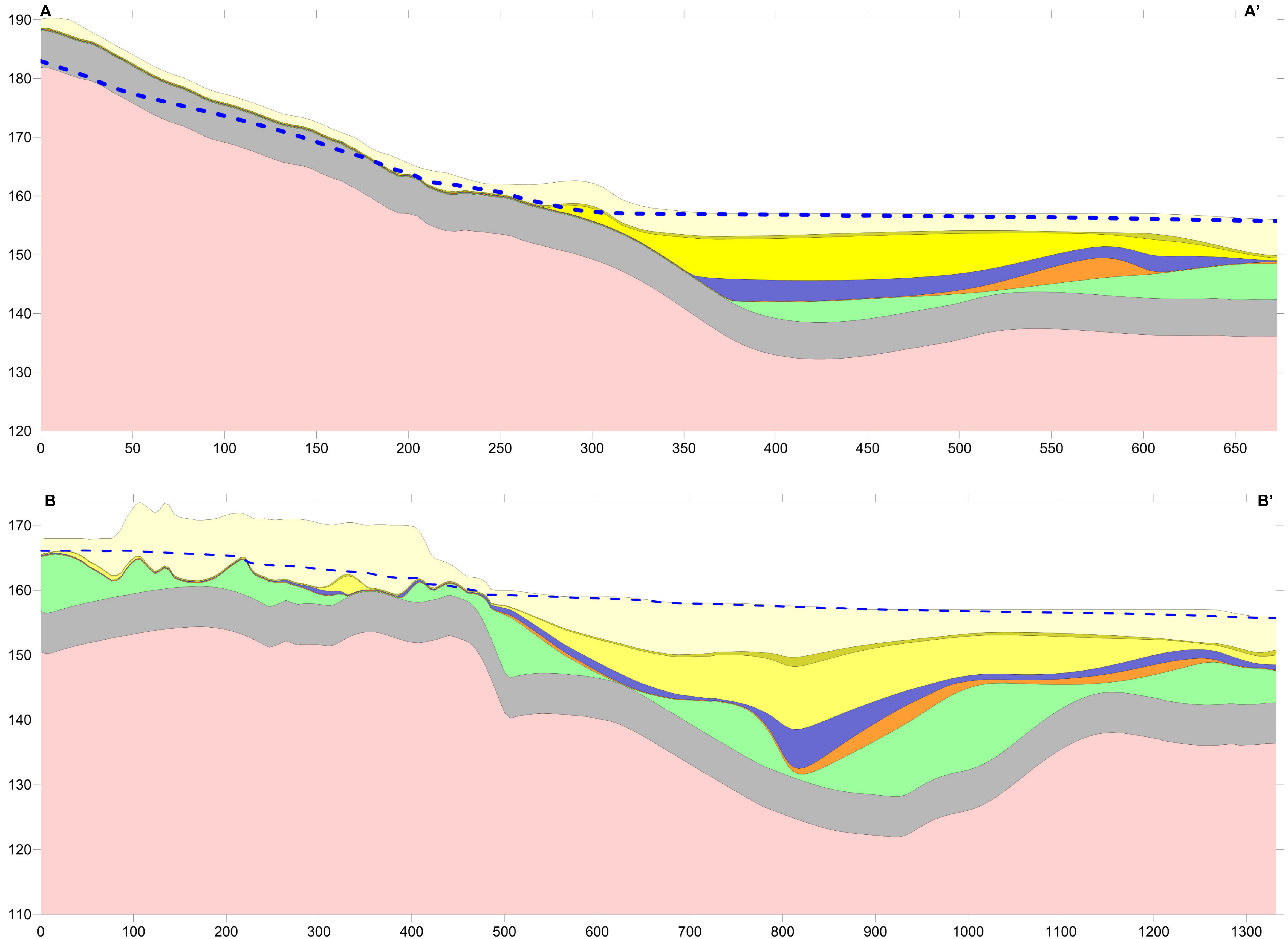
CONSULTANT
Golder Associates

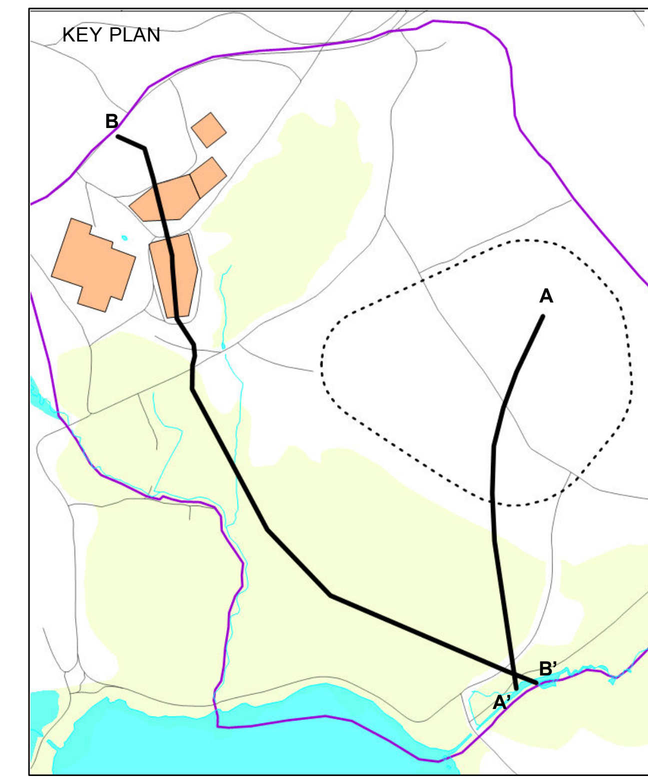
YYYY-MM-DD	2017-03-15
DESIGNED	NFB/MIB
PREPARED	SO/JR
REVIEWED	JL
APPROVED	GVA

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0011	0.0	**5.3.1-6**

LEGEND

- Upper Sand
- Interstratified Silt and Sand
- Middle Sand
- Clayey Silt
- Basal Sand
- Till
- Bedrock





NOTE(S)
1. VERTICAL EXAGGERATION IS 3.0.

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
STRATIGRAPHIC CROSS-SECTIONS FOR THE NEAR SURFACE DISPOSAL FACILITY PROJECT SITE

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	NFB/MIB
PREPARED	SO/JR
REVIEWED	MM
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.3.1-7

This page intentionally left blank

Glacial Till

The thickness of the glacial till unit within the NSDF Project Site is shown by an isopach on Figure 5.3.1-8. Glacial till covers a large portion of the bedrock surface and is thickest in the areas of the bedrock lows. Glacial till thins to the east towards the bedrock ridge. Where present, glacial till is generally less than 12 m thick, but reaches thicknesses of up to 15 m within the bedrock valley, and 20 m in the area to the north of the eastern bedrock ridge. Glacial till is locally thicker along a line that extends from the northern edge of the eastern bedrock ridge to the south of the East Swamp, ending approximately 250 m northeast of where the East Stream meets the Main Stream. In this area, the glacial till ranges from 3 to 8 m in thickness. Within the southern portion of the NSDF Project site (where bedrock is close to ground surface) the till is generally less than 1 m thick.

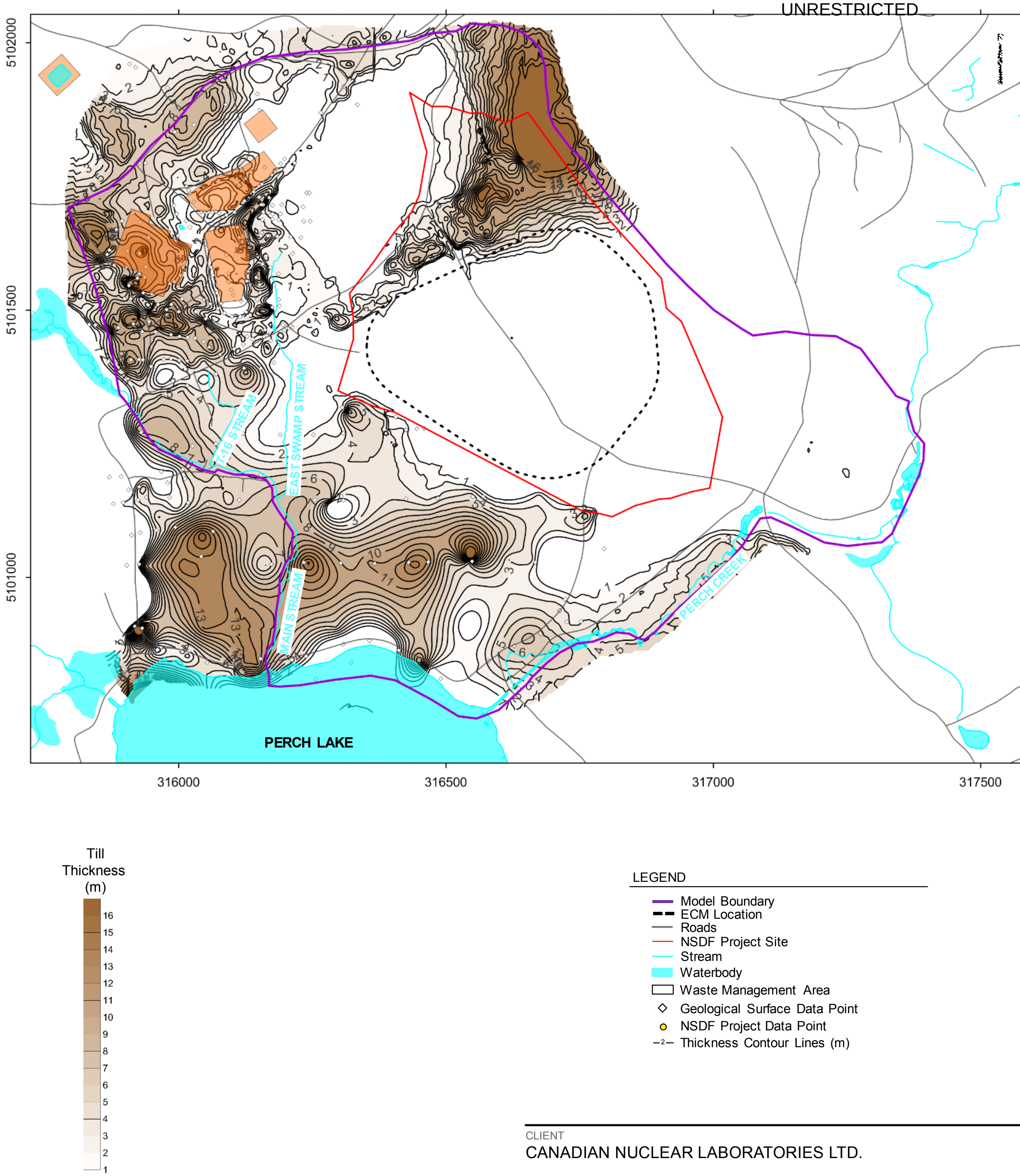
Glacial till within the Perch Lake Basin consists of poorly sorted boulders, cobbles and gravel in a silty sand to sandy silt matrix (Golder 2016), with no visible stratification (CNL 2016b). Grain size analyses indicate a low silt content (less than 10%) and a negligible clay content (CNL 2016b).

Basal Sand and Gravel

A basal sand and gravel unit overlies the glacial till in a limited area of the western portion of the Perch Lake Basin. The areal extent and thickness of this unit is shown by an isopach map on Figure 5.3.1-9. This unit ranges from 3.5 to 5.5 m in thickness within the bedrock valley to the north of Perch Lake and Perch Creek. The unit has also been found to underlie Waste Management Area A and the South Swamp, in thicknesses ranging from 1 to 4 m. This unit is not present in the NSDF Project site.

Clayey Silt

The thickness and areal extent of the clayey silt unit is shown as an isopach map on Figure 5.3.1-10. The clayey silt is generally present in the southwest portion of the Perch Lake Basin, where there are depressions in the surfaces of the till and the bedrock. Where present, the clayey silt is generally less than 2 m thick, but is more than 5 m thick in the bedrock depression approximately 200 m north of Perch Lake. North of the NSDF Project site, the clayey silt unit ranges in thickness from 0.5 to 1.5 m, being thickest to the east along East Mattawa Road. Clayey silt in the Perch Lake Basin is fluvial in origin and consists of laminations of coarser and finer fractions. The clay content of this unit, as determined through grain size analysis, is less than 20% by weight (CNL 2016b).



LEGEND

- Model Boundary
- ECM Location
- Roads
- NSDF Project Site
- Stream
- Waterbody
- Waste Management Area
- Geological Surface Data Point
- NSDF Project Data Point
- Thickness Contour Lines (m)

NOT TO SCALE

REFERENCE(S)

1. PERCH LAKE SUB-BASINS OBTAINED FROM E. ROBERTSON & P.J. BARRY (1985) THE WATER AND ENERGY BALANCES OF PERCH LAKE (1969–1980), ATMOSPHERE-OCEAN, 23:3, 238-253, DOI: 10.1080/07055900.1985.96492270)

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

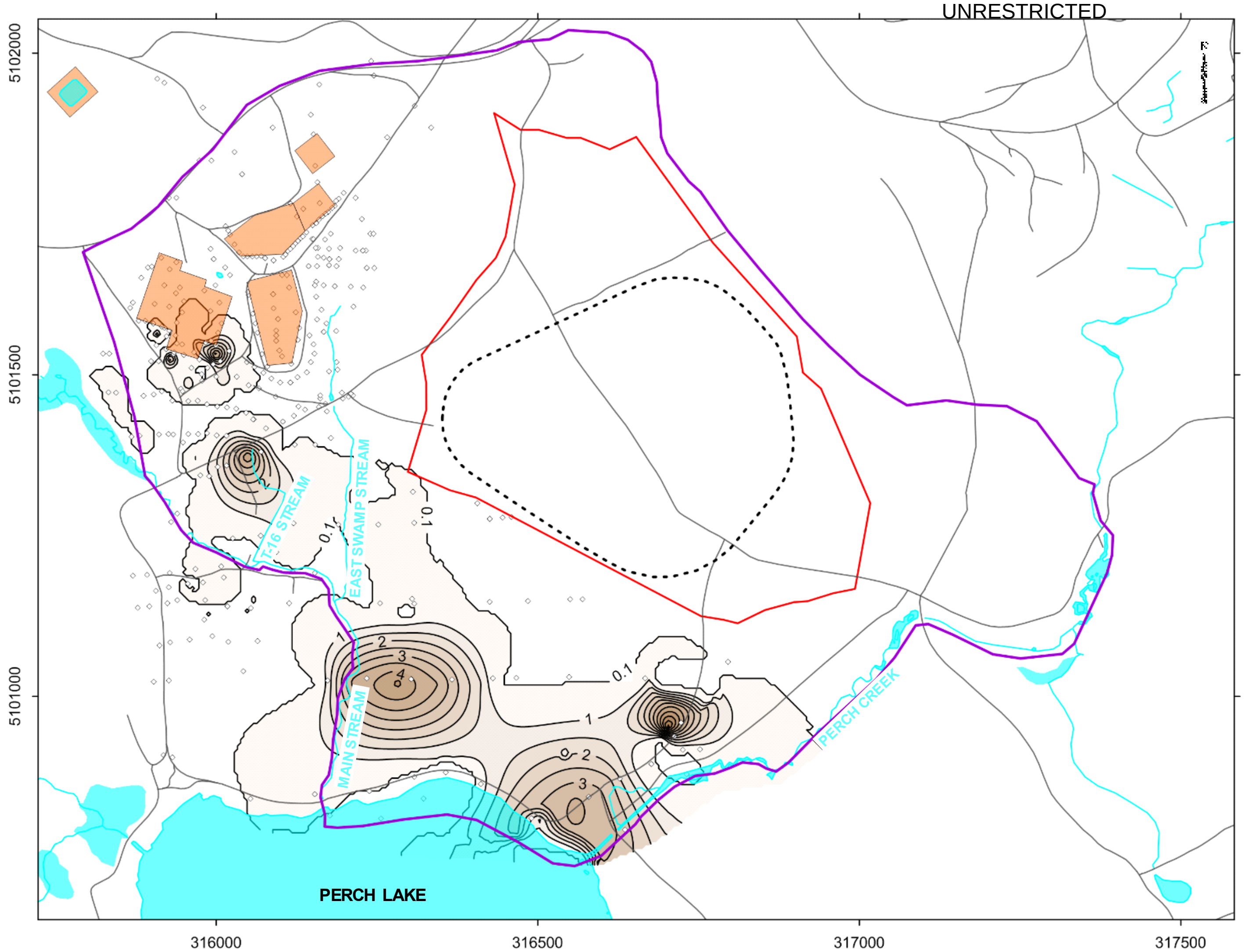
PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

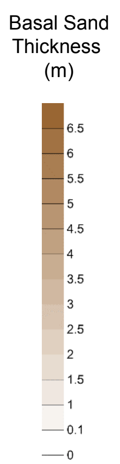
TITLE
ISOPACH MAP – AREAL EXTENT AND THICKNESS OF GLACIAL TILL UNIT FOR THE NSDF PROJECT SITE

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	NFB/MIB
PREPARED	SO/JR
REVIEWED	JL
APPROVED	GVA

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0011	0.0	5.3.1-8





LEGEND

- Model Boundary
- ECM Location
- Roads
- NSDF Project Site
- Stream
- Waterbody
- Waste Management Area
- Geological Surface Data Point
- NSDF Project Data Point
- Thickness Contour Lines (m)

NOT TO SCALE

REFERENCE(S)
1. PERCH LAKE SUB-BASINS OBTAINED FROM E. ROBERTSON & P.J. BARRY (1985) THE WATER AND ENERGY BALANCES OF PERCH LAKE (1969–1980), ATMOSPHERE-OCEAN, 23:3, 238-253, DOI: 10.1080/07055900.1985.96492270)

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
ISOPACH MAP – AREAL EXTENT AND THICKNESS OF BASAL SAND AND GRAVEL UNIT FOR THE NSDF PROJECT SITE

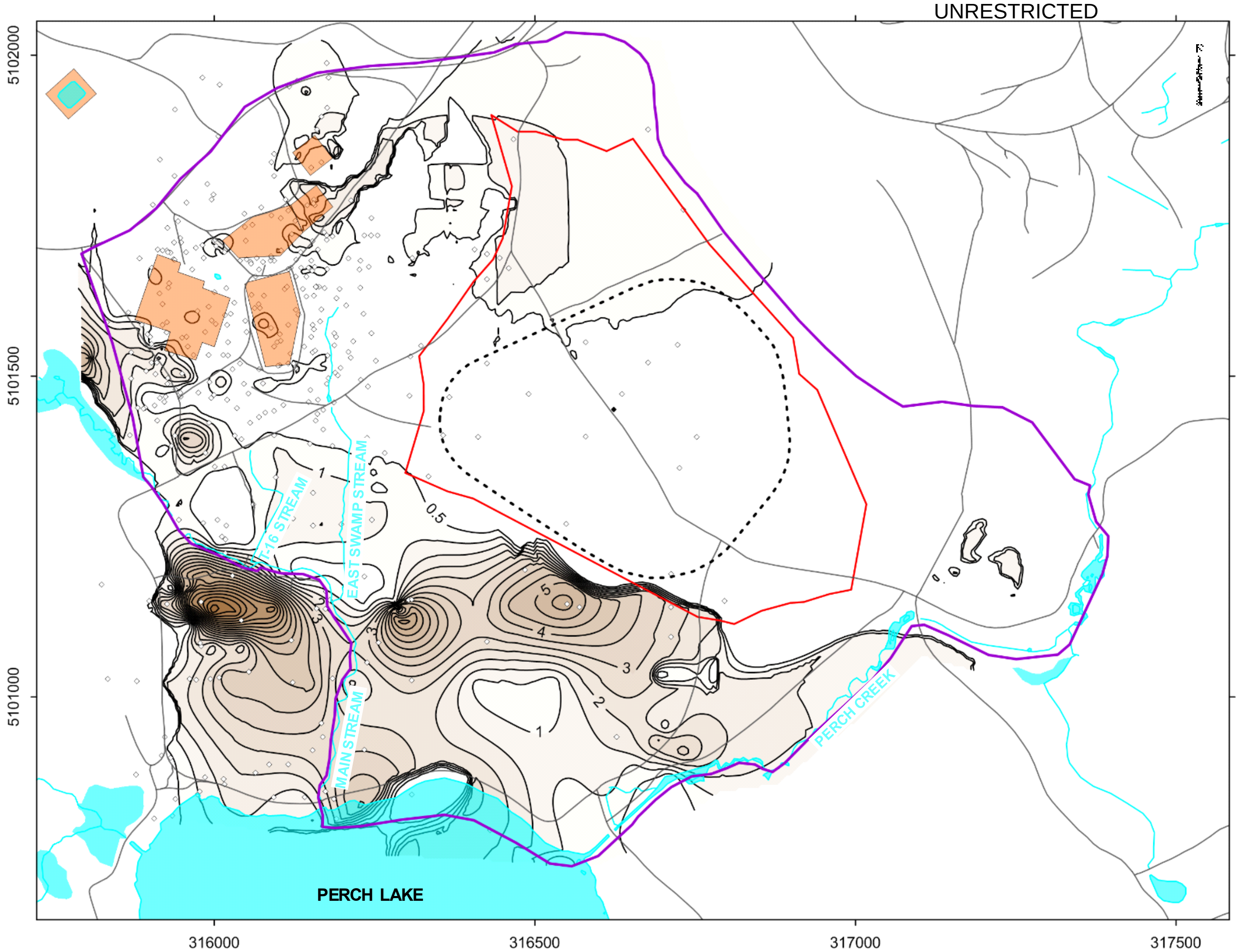
CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	NFB/MIB
PREPARED	SO/JR
REVIEWED	JL
APPROVED	GVA

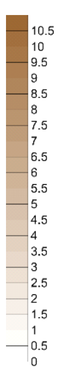
PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0011	0.0	5.3.1-9

Path: S:\Clients\Canadian_Nuclear_Laboratories\NSDF\99_PROJ\1547525_NSDF_EIS\40_PROD\0009_EIS_Section_5\Section_5.3_Geology_Hydrogeology\1547525-0009-CH-0009.mxd

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:
25mm



Clayey Silt Thickness (m)



LEGEND

- Model Boundary
- ECM Location
- Roads
- NSDF Project Site
- Stream
- Waterbody
- Waste Management Area
- Geological Surface Data Point
- NSDF Project Data Point
- Thickness Contour Lines (m)

NOT TO SCALE

REFERENCE(S)
1. PERCH LAKE SUB-BASINS OBTAINED FROM E. ROBERTSON & P.J. BARRY (1985) THE WATER AND ENERGY BALANCES OF PERCH LAKE (1969–1980), ATMOSPHERE-OCEAN, 23:3, 238-253, DOI: 10.1080/07055900.1985.96492270)

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
ISOPACH MAP – AREAL EXTENT AND THICKNESS OF CLAYEY SAND UNIT FOR THE NSDF PROJECT SITE

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	NFB/MIB
PREPARED	SO/JR
REVIEWED	JL
APPROVED	GVA

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0011	0.0	5.3.1-10

S:\Clients\Canadian_Nuclear_Laboratories\NSDF\99_PROJ\1547525_NSDF_EIS\40_PROD\0009_EIS_Section_5\Section_5.3_Geology_Hydrogeology\1547525-0009-CH-0010.mxd

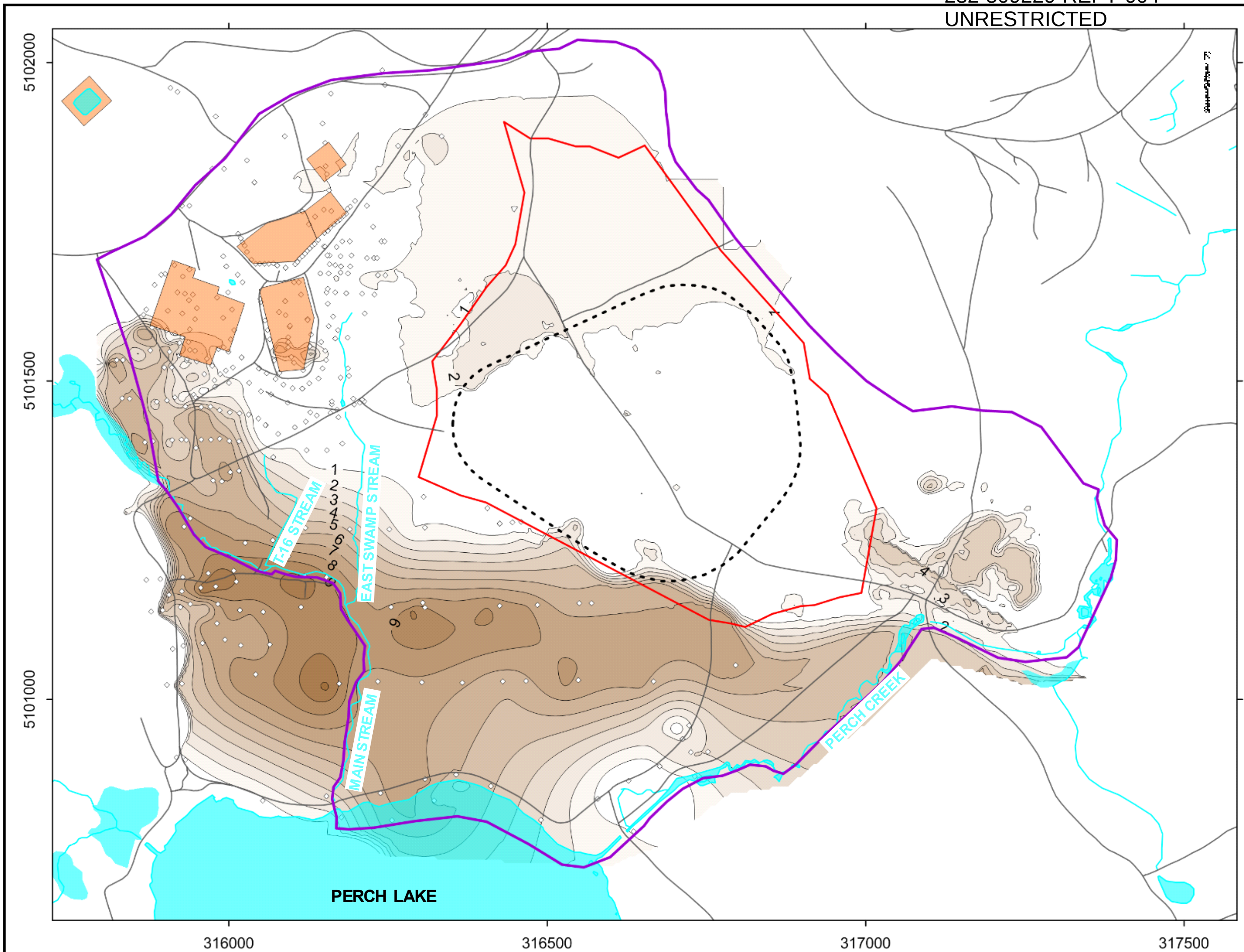
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm 0

Middle Sand

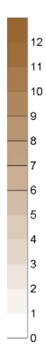
The extent and thickness of the middle sand unit is shown by an isopach map on Figure 5.3.1-11. As with the other sedimentary units, the middle sand is thickest in the areas of the bedrock depressions. This unit generally fills the bedrock valley and ranges in thickness from 2 m to 9 m in this area. Middle sand is also present in the southern portion of Reactor Pit 2 (up to 4 m in thickness) and on the northern and southern flanks of the eastern bedrock ridge that delineates the Perch Lake Basin (up to 3 m in thickness in the south and 2 m thickness in the north). The middle sand has been classified as moderately well sorted fine sand through the results of grain size analyses.

Interstratified Silt and Sand

The extent and thickness of the interstratified sand and silt unit is shown by an isopach map on Figure 5.3.1-12. Where present this unit is generally less than 0.4 m thick, but can reach thicknesses of up to 2 m locally (i.e., near the point of discharge from Perch Lake to Perch Creek and to the south and west of Waste Management Area A). This unit has been encountered in the northern portion of the NSDF Project site at thicknesses of less than 0.4 m. The interstratified silt and sand consists of alternating layers of fine to very fine sand and sandy silts. Individual layers are on the order of several centimetres (CNL 2016b).



Middle Sand Thickness (m)



LEGEND

- Model Boundary
- ECM Location
- Roads
- NSDF Project Site
- Stream
- Waterbody
- Waste Management Area
- Geological Surface Data Point
- NSDF Project Data Point
- Thickness Contour Lines (m)

NOT TO SCALE

REFERENCE(S)

1. PERCH LAKE SUB-BASINS OBTAINED FROM E. ROBERTSON & P.J. BARRY (1985) THE WATER AND ENERGY BALANCES OF PERCH LAKE (1969–1980), ATMOSPHERE-OCEAN, 23:3, 238-253, DOI: 10.1080/07055900.1985.96492270)

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
ISOPACH MAP – AREAL EXTENT AND THICKNESS OF MIDDLE SAND UNIT FOR THE NSDF PROJECT SITE

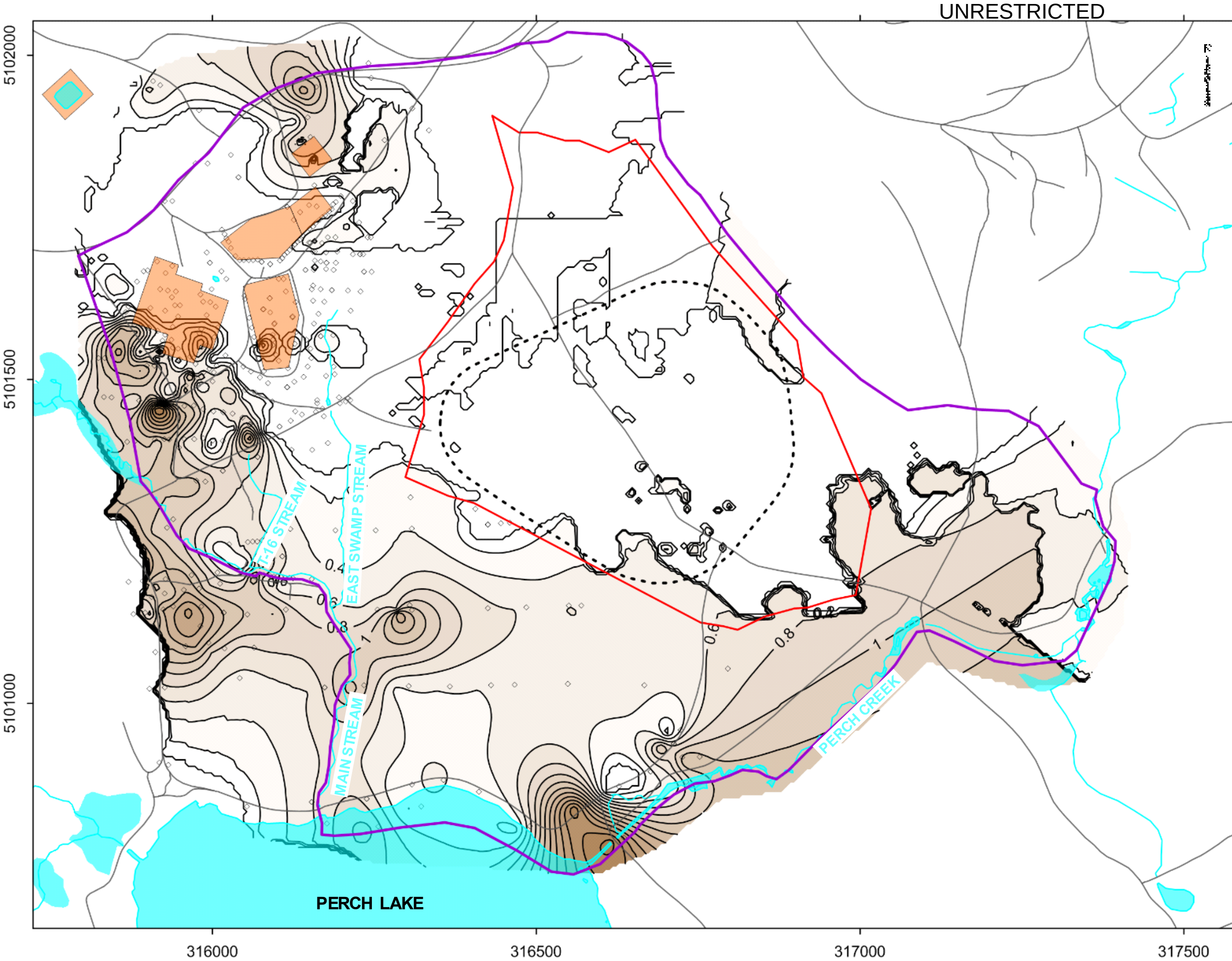
CONSULTANT
Golder Associates

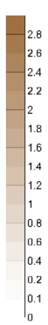
YYYY-MM-DD	2017-03-15
DESIGNED	NFB/MIB
PREPARED	SO/JR
REVIEWED	JL
APPROVED	GVA

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0011	0.0	5.3.1-11

Path: S:\Clients\Canadian_Nuclear_Laboratories\NSDF\99_PROJ\1547525_NSDF_EIS\40_PROD\0009_EIS_Section_5\Section_5.3_Geology_Hydrogeology\1547525-0009-CH-0011.mxd

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:
25mm





LEGEND

- Model Boundary
- ECM Location
- Roads
- NSDF Project Site
- Stream
- Waterbody
- Waste Management Area
- Geological Surface Data Point
- NSDF Project Data Point
- Thickness Contour Lines (m)

NOT TO SCALE

REFERENCE(S)
1. PERCH LAKE SUB-BASINS OBTAINED FROM E. ROBERTSON & P.J. BARRY (1985) THE WATER AND ENERGY BALANCES OF PERCH LAKE (1969–1980), ATMOSPHERE-OCEAN, 23:3, 238-253, DOI: 10.1080/07055900.1985.96492270)

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
ISOPACH MAP – AREAL EXTENT AND THICKNESS OF INTERSTRATIFIED SILT AND SAND UNIT FOR THE NSDF PROJECT SITE

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	NFB/MIB
PREPARED	SO/JR
REVIEWED	JL
APPROVED	GVA

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0011	0.0	5.3.1-12

Upper Sand

The upper sand unit is the uppermost sand unit in the Perch Lake Basin. The base of the upper sand unit is defined by either the top of the interstratified silt and sand unit, or by an inferred contact with the middle sand. The thickness of the upper sand unit is shown as an isopach map on Figure 5.3.1-13. The unit is thickest where the bedrock valley abuts the bedrock ridge that delineates the western boundary of the Perch Lake Basin. In this area, the unit can be up to 13 m thick. The upper sand unit is also locally thicker through an area extending from Plant Road, south through Reactor Pit 1 and Reactor Pit 2, then extending west through the southern portion of Waste Management Area A. In this area the unit reaches thicknesses of up to 10 m. The upper sand unit is present in the NSDF Project Site, at a relatively uniform thickness of approximately 1 m. There is a localized area to the immediate south west of the NSDF Project site, where the upper sand thickness increases to approximately 5 m. In comparison to the middle sand, the upper sand is slightly coarser and better sorted (CNL 2016b).

Surficial Soils

The LSA is located in the Brent Ecodistrict in the Georgian Bay Ecoregion of the Ontario Shield Ecozone. Ecodistricts are subdivisions of the region that are based on patterns of relief, geology, geomorphology and substrate parent material (Crins et. al. 2009). A layer of leaf litter and organic silt (topsoil), 50 to 230 millimetres (mm) thick was encountered at the ground surface. This material was generally a mixture of organic and mineral soil components. No purely organic soils were encountered during the 2016 geotechnical investigations (Golder 2016).

Soil substrates generally consist of well drained sandy soils in the LSA. The coarse grained parent materials have been derived from acidic gneissic and granitic rocks of the Precambrian shield, and as such, have aided in the development of Humo-ferric podzolic soils and to a lesser extent Melanic Brunisols (Gillespie et al. 1964). Organic peats and gleysols are found in poorly-drained sites and depressions (Crins et al. 2009). The dominant soil substrates in the LSA are coarse grained and organic/gleysolic (Table 5.3.1-3; Figure 5.3.1-14).

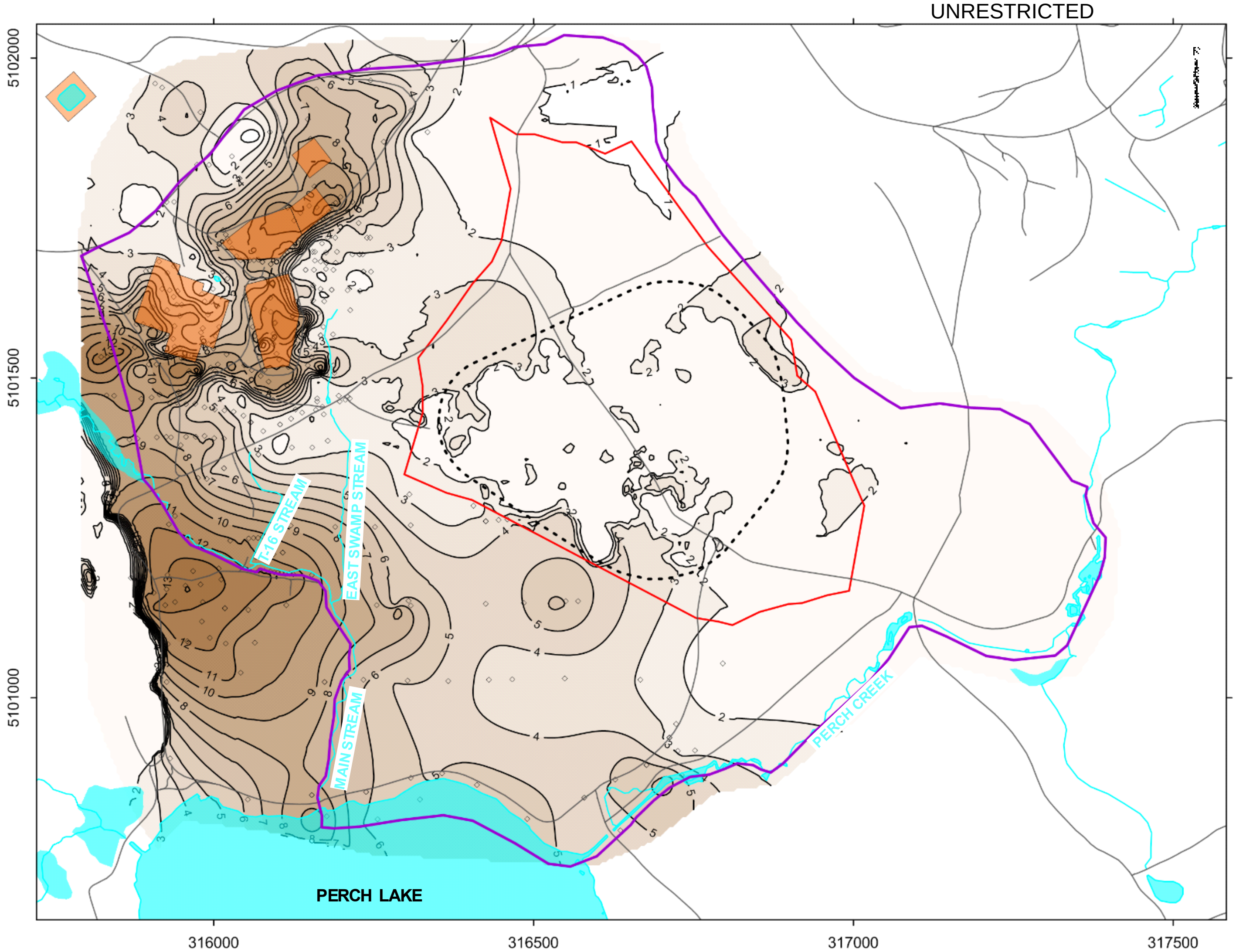
Table 5.3.1-3: Dominant Soil Orders in the Local Study Area

Dominant Soil Substrate	Area (ha)	Proportion (%)
Coarse Grained	54	31
Organic/Gleysolic	61	35
Water	41	23
Previously Disturbed	21	12
Total	177	100

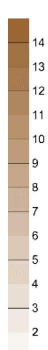
Source: Gendron Resource Surveys Ltd. 1987; MNRF 2016.
Numbers are rounded for presentation purposes. Therefore, it may appear that the totals do not equal the sum of the individual values.
ha = hectare; % = percent.

Drainage ranges from well-drained, coarse-textured soils to poorly and very poorly-drained organic soils in lower slope positions. Coarse-textured soils, with higher initial total porosity, are relatively resistant to compaction compared to finer textured soils found in other geographies (Carr et al. 1991); these soils are, however, prone to wind erosion. Sandy textured soils typically do not have a well-developed soil structure. The lack of soil structure is due to limited soil aggregation or adhesion of the soil particles and therefore, does not form larger and more stable soil aggregates. Aggregated soil particles are less likely to be moved by wind. Soil erosion risk is a concern for disturbed soils because the sparse vegetation cover exposes soil materials to the elements (e.g., wind and water).

Soil monitoring is not routinely performed as part of the CRL Environmental Monitoring Program and no data are available for soil quality within the NSDF Project site. Recent geotechnical investigations in 2016 (Golder 2016) in the LSA showed no evidence of contamination. Radiological contamination in the East Swamp wetland may be relevant to the NSDF Project, as this area is immediately west of the NSDF Project Site. The East Swamp wetland has existing contamination associated with a shallow subsurface plume from the Chemical Pit, and a second plume from Reactor Pit 2. The surface contamination distribution in the East Swamp has been characterized with radiation field surveys, surface surveys, and vegetation contamination surveys performed in 2002, 2007 and 2012. In 2002 and 2012, these surveys included wetland soil and vegetation sampling to determine the radionuclide concentrations in these media. These results are discussed in Section 5.7.4.7 Radioactivity in Soils.



Upper Sand Thickness (m)



LEGEND

- Model Boundary
- ECM Location
- Roads
- NSDF Project Site
- Stream
- Waterbody
- Waste Management Area
- Geological Surface Data Point
- NSDF Project Data Point
- Thickness Contour Lines (m)

NOT TO SCALE

REFERENCE(S)

1. PERCH LAKE SUB-BASINS OBTAINED FROM E. ROBERTSON & P.J. BARRY (1985) THE WATER AND ENERGY BALANCES OF PERCH LAKE (1969–1980), ATMOSPHERE-OCEAN, 23:3, 238-253, DOI: 10.1080/07055900.1985.96492270)

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
ISOPACH MAP – AREAL EXTENT AND THICKNESS OF UPPER SAND UNIT FOR THE NSDF PROJECT SITE

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	NFB/MIB
PREPARED	SO/JR
REVIEWED	JL
APPROVED	GVA

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0011	0.0	**5.3.1-13**

LEGEND

- HIGHWAY
- ROAD
- TRANSMISSION LINE
- RIVER/STREAM
- WATERBODY
- WETLAND
- CRL MAIN CAMPUS
- WASTE MANAGEMENT AREA (WMA)[1]
- NEAR SURFACE DISPOSAL FACILITY (NSDF)
- CRL PROPERTY
- LOCAL STUDY AREA

DOMINANT SOIL ORDERS

- COARSE TEXTURED
- ORGANIC/GLEYSOL
- DISTURBED

250 0 250
1:10,000 METRES

NOTE(S)

1. LIQUID DISPOSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.

REFERENCE(S)

1. BASEDATA MNRF 2016 AND CANVEC 2016
2. IMAGERY: SOURCE: ESRI, DIGITALGLOBE, GEOEYE, EARTHSTAR GEOGRAPHICS, CNES/AIRBUS DS, USDA, USGS, AEROGRID, IGN, AND THE GIS USER COMMUNITY
3. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016)
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE18N

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
DOMINANT SOIL ORDERS IN THE LOCAL STUDY AREA

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	KH
APPROVED	MM

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.3.1-14

This page left intentionally blank

5.3.1.5 *Project Interactions and Mitigation*

5.3.1.5.1 Methods

This section describes the process by which interactions between NSDF Project components and activities and groundwater quantity and quality were identified and evaluated. Potential effect pathways are identified and mitigation developed to eliminate and/or reduce effects is presented. A pathways analysis is then used to focus the assessment on key interactions between the NSDF Project and the environment by evaluating the different effect pathways to determine if, after incorporation of mitigation, there is still potential to cause residual effects. Where effects will be adequately mitigated and are not forwarded for further analysis (i.e., secondary pathways, or where mitigation will remove the pathway altogether), the reasons for concluding the assessment at this stage are articulated. Primary pathways that may lead to residual effects after incorporation of mitigation are further characterized in subsequent subsections of the assessment (i.e., Section 5.3.1.6). As such, the "Project Interactions and Mitigation" section helps to focus the remainder of the assessment on those interactions (effects pathways) likely to result in residual adverse effects.

The first part of the analysis was to identify the potential effects pathways for all phases of the NSDF Project. The next step in the analysis was the development of environmental design features and mitigation that could be incorporated into the NSDF Project to eliminate and/or reduce adverse effects to geology. Environmental design features included Project design elements, environmental best practices and management policies and procedures. Environmental design features and mitigation were developed through an iterative process between the Project's engineering and environmental teams, combined with input from Project-specific or regional engagement with other interested parties. The environmental design features and/or mitigation were selected considering their effectiveness for implementation and maintenance and their appropriateness within the context of the identified effect pathways.

After incorporation of mitigation, potential pathways were evaluated into the following categories using scientific knowledge, logic, experience with similar developments and the effectiveness of environmental design features and mitigation:

- **No pathway –** pathway is removed by environmental design features or mitigation such that the Project would not be expected to result in a measurable environmental change relative to Base Case values and therefore would have no residual effects geology.
- **Secondary pathway –** the pathway could result in a measurable minor environmental change, but would have a negligible residual effect on geology relative to Base Case and/or guideline values and is not expected to contribute cumulatively to other Project effects or to the effects of other past, present or reasonably foreseeable developments to cause a significant effect.
- **Primary pathway –** the pathway is likely to result in an environmental change relative to the Base Case and/or guideline values that could contribute to residual effects to geology.

Environmental design features and mitigation that have been or could be incorporated into the Project to eliminate and/or reduce adverse effects were considered. Potential pathways that were completely removed due to implementation of environmental design or mitigation were not assessed further. Pathways that were assessed to be secondary and demonstrated to have a negligible residual effect to geology through simple qualitative or semi-quantitative evaluation of the pathway were also not advanced for further assessment. Primary pathways were carried forward for more detailed quantitative and qualitative effects analysis to characterize the residual effects of the Project.

5.3.1.5.2 Results

Pathways through which all stages of the Project may interact with and result in changes to measurement indicators for geology is provided in Table 5.3.1-4.

Table 5.3.1-4: Pathways Analysis for Geology Valued Components

<table>
<tr><th>Project Activity</th><th>Effects Pathways</th><th>Management Practices and Mitigation</th><th>Pathway Assessment</th></tr>
<tr><td rowspan="2">■ Project activities during the construction phase:
▪ Site Preparation
▪ Construction of the Engineered Containment Mound (ECM)
▪ Blasting (as required)
▪ Development of surface water management structures
▪ Construction of the Wate Water Treatment Plant (WWTP) and other support facilities
▪ On-site road and access development</td><td>■ Construction activities can alter soil quantity, quality and distribution.
■ Construction activities can alter geomorphology.</td><td>■ The NSDF Project footprint has been designed to avoid wetlands and limit disturbance to the natural environment to the extent feasible. For example, as the ECM is developed sequentially, undeveloped cells may be prepared and used as stockpile areas to store overburden soils to be used during construction or for daily/interim cover stockpiles. This approach reduces the required area for the laydown and stockpile of materials.
■ Erosion and sediment control practices (e.g., silt fences, runoff management) applicable to the region and already in place at the CRL property (i.e., CNL’s Management of Land and Habitat Procedure) will be used during construction around disturbed areas, where appropriate.</td><td>Secondary</td></tr>
<tr><td>Blasting residuals and metals may be released during construction of the ECM and surface water drainage features through the NSDF Project site may cause changes to soil quality.</td><td>■ Blasting activities will follow industry standard Best Management Practices and applicable federal regulations.
■ Additional guidance for the NSDF Project blasting limits will be obtained from the Ontario Provincial Standards (OPSS) in the document OPSS 120 – General Specification for Use of Explosives (OPSS 2008).</td><td>Secondary</td></tr>
</table>

Table 5.3.1-4: Pathways Analysis for Geology Valued Components

Project Activity	Effects Pathways	Management Practices and Mitigation	Pathway Assessment
■ Project activities during the construction phase (as described above) ■ Project activities during the operation phase: ▪ On-site transportation of waste and placement in the ECM ▪ Progressive closure of disposal cells and installation of cover ▪ Surface water management ▪ Domestic waste (solid and liquid) management; and, ▪ Routine operational management and monitoring activities.	General activities that require the use of vehicles and equipment that combust fuel and emit criteria air contaminants (CACs). These activities involve material handling, vehicles travelling on paved and unpaved roads, and wind erosion of stockpiles that will result in fugitive dust emissions. Air and dust emissions and subsequent deposition may cause a change in soil quality.	■ Implementation of CNL's Procedure for Management and Monitoring of Emissions, which includes operational control monitoring, verification monitoring and environmental monitoring. ■ The Dust Management Plan for the NSDF Project will be developed and will include: ▪ restricting or suspending activities if unacceptable amounts of dust are generated due to winds or other site conditions; ▪ use of water spraying or misting techniques (e.g., water trucks) as the primary dust control method; ▪ use of fixatives (e.g., chemical suppressant) for dust control during winter season or shutdown periods, and for use as daily/interim cover; ▪ suspension of excavating, loading, hauling, and dumping operations when wind speeds exceed the specified criterion; and ▪ vehicles that have come into contact with contamination will be required to pass through the vehicle decontamination facility. ■ On-site vehicles and equipment engines will meet Tier 2 emission standards and be maintained in good working order. ■ Limit idling of vehicles on-site.	Secondary

Table 5.3.1-4: Pathways Analysis for Geology Valued Components

Project Activity	Effects Pathways	Management Practices and Mitigation	Pathway Assessment
General Project activities during the construction phase and operation phases (as described above)	Surface water runoff from the NSDF site can alther soil quantity, quality and distribution	■ Procedures for surface water management will be developed and implemented for the NSDF Project. ■ Erosion and sediment control practices (e.g., silt fences, runoff management) applicable to the region and already in place at the CRL property (i.e., CNL's Management of Land and Habitat Procedure) will be used around disturbed areas, where appropriate. ■ The target surface water quality objective is provided by MOECC in Stormwater Management Planning and Design Manual (MOECC 2003). ■ Surface water from all external areas will be conveyed by ditches, swales and culverts to surface water management ponds tol address water quality and water quantity criteria established for the wetland receiving waters and, ultimately, Perch Creek. ■ The surface water management ponds are designed to address erosion and sediment control concerns during construction by providing interim sediment control and by providing water quality/quantity controls during operations, closure, and post-closure. ■ The current surface water management pond footprints reflect the overall storage required to control post-closure flows to predevelopment levels for the 2-year through to 100-year rainfall events at the site. This volume also contains the storage required for sediment control during construction and water quality control during operations.	No Linkage

Table 5.3.1-4: Pathways Analysis for Geology Valued Components

Project Activity	Effects Pathways	Management Practices and Mitigation	Pathway Assessment
■ Project activities during the operations and closure phases: ▪ Surface water management ▪ Operation of the WWTP	Leakage of leachate from the ECM during operations and closure may cause changes to groundwater quality, which can affect soil quality	■ Design of the ECM includes base contours that have been developed using a herringbone pattern with ridges and valleys to promote leachate transport to the leachate collection system for removal. ■ The base liner design includes both primary and secondary liner systems that are designed to have redundancy in case of premature failure and are a combination of natural and synthetic barrier systems. ■ The HDPE geomembrane for the liner was selected as it is compatible with the leachate generated by the waste and achieves a long service life. ■ The base liner system includes an underlying compacted clay liner to supplement the primary and secondary liner system. ■ The leachate collection and monitoring system design provides access points for monitoring, inspections, maintenance, repairs and replacements. ■	No Linkage
■ Project activities during the closure and post-closure phases: ▪ Maintenance of fencing around perimeter of ECM ▪ Installation of final ECM cover, restoration and grading of SSA ▪ On-going long-term performance monitoring, transfer of NSDF Project into Institutional Control	The installation of the final cover of the ECM and decommissioning and site grading of NSDF Project site can cause increased erosion and alter soil quality, quantity and distribution.	■ The final cover is designed to promote positive drainage from the NSDF Project site and reduce erosion or abrasion of the cover. ■ Performance monitoring will be completed throughout the post-closure phase for the NSDF Project to confirm that the cover is functioning as intended.	Secondary

5.3.1.5.2.1 No Linkage Pathways

The following pathways were assessed as having no measurable environmental change and hence, no linkage to residual effects on geology VCs.

- **Surface water runoff from the NSDF site can alther soil quantity, quality and distribution.**

The surface water management ponds are designed to address erosion and sediment control concerns during construction by providing interim sediment control and by providing water quality/quantity controls during operations, closure, and post-closure. The current surface water management pond footprints reflect the overall storage required to control post-closure flows to predevelopment levels for the 2-year through to 100-year rainfall events at the site. This volume also contains the storage required for sediment control during construction and water quality control during operations. The target surface water quality objective is provided by the Ministry of Environment and Climate Change (MOECC) in Stormwater Management Planning and Design Manual (MOECC 2003), which reports a 60% total suspended solids (TSS) removal that provides a basic water quality treatment for discharge to the receiving wetland.

During the construction phase, erosion and sediment control measures will be in place to mitigate the effects of soil erosion and sediment transport. The measures include the use of erosion control blankets, as needed, to control erosion on steep slopes, check dams in ditches and swales, and the three proposed surface water management ponds that will be constructed to serve as interim sediment control facilities during construction, and then as stormwater management facilities during the operations, expansion and post-closure periods. Erosion and sediment control practices (e.g., silt fences, runoff management) applicable to the region and already in place at the CRL property (i.e., CNL’s Management of Land and Habitat Procedure) will be used around disturbed areas, where appropriate.

Site operations include surface water management for the Engineered Containment Mound (ECM) and all external areas. Surface water from all external areas will be conveyed by ditches, swales and culverts to surface water management ponds that will address water quality and water quantity criteria established for the wetland receiving waters and, ultimately, Perch Creek. Contact surface water drainage from the active cells of the ECM will be to the WWTP. Non-contact surface water drainage from completed cells and yet-to-be-activated cells will be directed either by gravity to the external surface water management system or to temporary holding ponds within the ECM, and then pumped to the three surface water management ponds. There will be a need to address pre-treatment of surface water run-off from the active cells prior to conveyance to the WWTP and a need to establish conveyance mechanisms (gravity and pumping) from the interior of the ECM to the surface water management ponds.

Facility inspections will be completed twice annually to confirm that inlets and outlets are clear of debris and to confirm that there are no major erosion issues at the inlet or outlet. As well, the integrity of berms and outlet structures will be confirmed by visual inspections (e.g., to identify any animal burrowing activity or active soil erosion). Inspections will also include an annual sediment level monitoring component within each pond to identify sediment accumulation rates that may require clean-out requirements. If necessary, pond sediment will be extracted by excavation equipment and will be disposed of based on sediment sampling, testing, and classification according to MOECC standards, or stockpiled, de-watered and re-used on-site for ECM cover operations. Sediment removal will follow procedures identified in the Stormwater Management Planning and Design Manual (MOECC 2003).

Roadway, sidewalk, and parking lot winter maintenance activities that may release road salt to the environment, include snow plowing/shoveling and de-icing practices, salt and sand storage and snow stockpiling, removal, and disposal. The current winter maintenance practices outlined in the CRL Salt Management Plan provide for effective management of salt use, and will be applied to the NSDF Project, as necessary. As per the plan, the application of road salt on the NSDF site will be to be limited as salt residual within contact water and/or leachate may compromise the treatment effectiveness of the WWTP systems. Instead, alternative products in winter road management, such as a sand-stone mixtures, are currently being considered.

Overall, the implementation of the above mentioned mitigation measures will reduce the potential for changes to soil quality, quantity and distribution. As such, this pathway was determined to have no linkage to effects on geology.

- **Leakage of leachate from the ECM during operations and closure may cause changes to groundwater quality, which can affect soil quality.**

Design of the ECM includes base contours that have been developed using a herringbone pattern with ridges and valleys to promote leachate transport to the leachate collection system for removal. The base liner design includes both primary and secondary liner systems that are designed provide redundancy in case of premature failure and are a combination of natural and synthetic barrier systems. The primary liner includes a leachate collection system with the secondary liner housing a leak detection system. The composite base liner contains perforated high-density polyethylene (HDPE) collection and pipes. The HDPE geomembrane was selected as it is compatible with the leachate generated by the waste and is expected to perform as an effective hydraulic and diffusion barrier over the 500-year design life (see Section 3.5.2.4). The base liner system includes an underlying compacted clay liner to supplement the primary and secondary liner system. The leachate collection system design provides access points for inspections, maintenance, repairs and replacements.

The primary liner system will contain the leachate collection system, and will convey leachate to a single collection point for removal from the mound, for transfer to the WWTP for treatment. The primary liner system serves as the primary source of protection for the natural environment below the mound from leachate migration. The secondary liner system will contain the leak detection system, which will be used to detect leaks in the unlikely event that the primary liner system fails. Leachate collected by the leachate collection system will be pumped to the onsite WWTP for treatment.

Designed berms consist of three main geotechnical elements, or layers, each contributing to the soundness and integrity of the berm itself and the whole ECM. A Slope Stability Analysis was completed to provide the information needed to support the design of the base slopes, sidewalls, and side slopes of the ECM. The Slope Stability Analysis addresses the range of anticipated loading conditions, under both short-term and long-term scenarios, to confirm that the slope designs will satisfy minimum factor-of-safety requirements for stability. Size and shape of the berms and each of the elements and layers were determined using a seismic design basis, including the National Building Code of Canada (NBCCC).

Overall, implementation of the above mentioned mitigation measures will reduce the potential for changes to groundwater water quality from the NSDF site. As such, this pathway was determined to have no linkage to effects geology.

5.3.1.5.2.2 Secondary Pathways

The following pathways were assessed as potentially having a measurable minor environmental change, but resulting in a negligible residual effect on geology relative to the Base Case.

- **Construction activities can alter soil quantity, quality and distribution.**
- **Construction activities can alter geomorphology.**
- **The installation of the final cover of the ECM and decommissioning and site grading of NSDF Project site can cause increased erosion and alter soil quality, quantity and distribution.**

Changes to surface flows, water levels, and water quality from NSDF Project construction and decommissioning are expected to be limited using environmental design features and mitigation. The NSDF Project footprint was designed to be as small as possible to limit disturbance to the natural environment to the extent feasible and will avoid stream and wetland habitats. For example, as the ECM is developed sequentially, undeveloped cells may be prepared and used as stockpile areas to store overburden soils to be used during construction or for daily/interim cover stockpiles. This approach reduces the required area for the laydown and stockpile of materials. Excavation for the ECM, drainage ditches, and the surface water management ponds will be completed once the NSDF Project Site has been cleared and topsoil removed.

During the construction phase, erosion and sediment control measures will be in place to mitigate the effects of soil erosion and sediment transport. The measures include the use of erosion control blankets, as needed, to control erosion on steep slopes, check dams in ditches and swales, and the three proposed surface water management ponds that will be constructed to serve as interim sediment control facilities during construction, and then as stormwater management facilities during the operations, expansion and post-closure periods. Erosion and sediment control practices (e.g., silt fences, runoff management) applicable to the region and already in place at the CRL property (i.e., CNL's Management of Land and Habitat Procedure) will be used around disturbed areas, where appropriate. Closure activities include the installation of an engineered cover over the ECM to limit ponding and water infiltration in to the waste. Modification to the drainage ditches and conveyance channels will be made to promote positive drainage from the site and limit erosion or abrasion of the cover. Run-off control for the cover is designed to limit ponding and infiltration of water into the ECM, erosion of the cover and waste material, and destabilization of the structure. The ECM design approach is to control the direction and velocity of the run-off to prevent erosion and abrasion of the cover. Any surface water infiltrating the final cover will be collected by the leachate collection system and sent to the WWTP. The three surface water management ponds will remain to promote infiltration and settlement of suspended solids and restrict discharge rates to the nearby wetland. Decommissioning of the WWTP and all associated surface water management structures will be completed after the leachate quantity and quality no longer requires treatment.

Environmental monitoring will be completed throughout the post-closure phase for the NSDF Project to confirm that the cover is functioning as intended. Overall, changes to soil quantity and quality from the NSDF Project footprint, and changes to geomorphology from the closure activities was determined to have no residual effect on geology.

- **Blasting residuals and metals may be released during construction of the ECM and surface water drainage features through the NSDF Project site may cause changes to soil quality.**

Use of explosives during the construction phase of the NSDF Project could cause changes in soil quality. Explosives have the potential to release nitrogen residual substances (e.g., ammonium nitrate/fuel oil [ANFO]). Blasting activities and the removal of waste rock could increase dust deposition and could increase trace metal (e.g., aluminum, cadmium, chromium, copper, iron, mercury, and silver) concentrations and nitrogen residual substances.

The approved Blasting Plan will provide mitigation to limit the potential for effects on soil quality from fugitive dust generation through excavation and material transport. Additional guidance will be obtained from the Ontario Provincial Standard Specification (OPSS) in the document OPSS 120 – General Specification for Use of Explosives (OPSS 2008). Any runoff in contact with blasting residues at the NSDF Project site will be managed where appropriate (e.g., surface water management ponds) during the construction phase to avoid adverse environmental effects off-site. Consequently, changes to soil quality from the use of explosives was determined to have a negligible residual effect on geology.

- **General activities that require the use of vehicles and equipment that combust fuel and emit CACs. These activities involve material handling, vehicles travelling on paved and unpaved roads, and wind erosion of stockpiles that will result in fugitive dust emissions. Air and dust emissions and subsequent deposition may cause a change in soil quality.**

Construction and operation of the NSDF Project will generate air and dust emissions such as carbon monoxide (CO), oxides of sulphur (SOx includes sulphur dioxide [SO2]), oxides of nitrogen (NOx includes nitrogen dioxide NO_2), particulate matter ($PM_{2.5}$), and suspended particulate matter (SPM). Air emissions such as SOx and NOx can result from the use of fossil fuels in generators, vehicles and machinery. Vehicle exhaust and fugitive dust from unpaved and paved roads is the largest contributor to particulate matter (SPM, PM_{10}, and $PM_{2.5}$) during both construction and operations (Section 5.2.1.6.2).

Examples of mitigation practices implemented to limit predicted residual effects from NSDF Project emissions to air quality (and subsequently surface water quality) include:

- implementation of CNL's Procedure for Management and Monitoring of Emissions, which includes operational control monitoring and verification monitoring;
- development and implementation of the Dust Management Plan for the NSDF Project;
- the primary dust control method will include water spraying or misting techniques (e.g., water trucks);
- on-site vehicles and equipment engines will meet Tier 2 emission standards and be maintained in good working order; and
- limiting idling of vehicles on-site.

Dust control will be conducted to support waste placement operations in accordance with the Dust Management Plan during loading, transportation, placement and compaction operations. Work areas that have the potential for generating dust will require implementation of dust suppression technique. The primary dust control method will include water spraying or misting techniques (e.g., water trucks). Water application is controlled to avoid

generation of free liquids. Fixatives (e.g., chemical suppressant) may also be used for dust control during winter season or shutdown periods, and for use as daily/interim cover. The use of fixatives is reviewed prior to application for potential effects on leachate and surface water runoff generated by the ECM.

Vehicle exhaust and fugitive dust from unpaved roads is the largest contributor to particulate matter (SPM, PM_{10}, and $PM_{2.5}$) during both the construction and operations phases. Vehicle exhaust during the construction of the ECM is the largest contributor of NO_x/NO_2 and CO. Predicted concentrations for the Application Case during both construction and operations phases are below applicable air quality guidelines and/or standards (Section 5.2.1.6.2, Table 5.2.1-14). With the implementation of CNL's Management and Monitoring of Emissions Procedure and through the implementation of the Dust Management Plan for the NSDF Project, air and dust emissions and subsequent deposition are expected to result in minor and local changes to surface water quality relative to Base Case conditions. Therefore, this pathway was determined to have negligible effects on geology.

5.3.1.5.2.3 Primary Pathways

No primary pathways were identified as having a residual effects on geology. As such, a residual effects analysis and determination of significance is not required for geology.

5.3.1.6 Monitoring and Follow-up

Monitoring and follow-up programs are not specifically identified for geology; rather, operational monitoring will be implemented to verify effects predictions for geology. For example, visual inspections of the NSDF Project site and surface water management systems will be completed to confirm erosion control practices are effective. This monitoring will be integrated into the NSDF Environmental Protection Plan to be developed and implemented for the NSDF Project.

5.3.1.7 Conclusions

Valued components refer to environmental features that may be affected by a project and that have been identified to be of concern by the proponent, scientists, government agencies, First Nation and Métis peoples, or the public (The Agency 2014). Geology, which includes bedrock, soils and geomorphology, is recognized as an important component of the environment that may be affected by the NSDF Project and changes to geology could, in turn, lead to effects on other VCs selected for assessment. Acknowledging that changes to geology are considered to be important aspects of the natural and human environment, geology is referred to as an intermediate component. Results of the analysis of changes in measurement indicators for geology are provided to other disciplines for inclusion in their assessment.

Potential effects on geology are related to changes in soil quantity and quality, and geomorphology as a result of construction of the NSDF Project, and changes to soil quality from blasting activities and air emissions. Mitigation and environmental design features implemented for the NSDF Project are well-understood and include existing practices at the CRL site. For example, a Blasting Plan and Dust Management Plan will provide mitigation to limit the potential for effects on soil quality from fugitive dust generation through excavation and material transport. Consequently, no residual effects on geology are predicted as a result of the NSDF Project. Monitoring and follow-up programs are not specifically identified for geology; rather, operational monitoring will be implemented to verify effects predictions for geology. This monitoring will be integrated into the NSDF Environmental Protection Plan to be developed and implemented for the NSDF Project.

5.3.2 Hydrogeology

5.3.2.1 Scope of the Assessment

This section focuses on hydrogeology and follows the overall environmental assessment approach and methods described in Section 5.1. The assessment is completed in the following key steps:

- **Step 1 – Identify Valued Components (VCs) and define the spatial boundaries, temporal boundaries and assessment cases** for the hydrogeology assessment (refer to Sections 5.3.2.2 Valued Components and 5.3.2.3 Assessment Boundaries). The VCs and measurement indicators used to assess NSDF Project-related changes to hydrogeology; the spatial and temporal boundaries at which the assessment occurred; and, the assessment cases considered are described.

- **Step 2 – Describe the existing conditions** (refer to Section 5.3.2.4 Description of the Environment). Existing conditions in the local and regional areas are described, including the combined effects of previous and existing developments (Base Case). The existing environment represents the historical and current environmental pressures that have shaped the observed patterns in the environment (i.e., natural variation).

- **Step 3 – Evaluate Project interactions and mitigation** (refer to Section 5.3.2.5 Project Interactions and Mitigation). Project components and/or activities with the potential to affect hydrogeology are identified and mitigation developed to limit or avoid effects is presented. A pathways analysis is then used to focus further assessment on key interactions between the NSDF Project and the environment by evaluating the different effect pathways to determine if, after incorporation of mitigation, there is still potential to cause residual effects. Where effects are adequately mitigated and are not forwarded for further analysis (i.e., secondary pathways, or where mitigation will remove the pathway altogether), the reasons for concluding the assessment at this stage are articulated. Primary pathways that may lead to residual effects to hydrogeology after incorporating mitigation are carried forward to Steps 4 for further analysis and residual effects characterization.

- **Step 4 – Present the methods and results of the residual effects analysis** (refer to Section 5.3.2.6 Residual Effects Analysis). This section outlines the methods used to predict and characterize residual effects to hydrogeology from primary effect pathways. The analysis results are also presented including the characterization of: (i) residual incremental effects of the NSDF Project and the effects of the Project in combination with past and present developments on hydrogeology (Application Case); and (ii) residual effects of the Project in combination with past and present developments, as well as other reasonably foreseeable developments (Reasonably Foreseeable Development Case). A key outcome of this section is the predicted effects to hydrogeology that are passed on to other VCs for inclusion in their assessment.

- **Step 5 – Describe the level of certainty and management of uncertainty** (refer to Section 5.3.2.7 Prediction Confidence and Uncertainty). Evaluate the available literature, data and models used for the assessment, and describe the level of certainty that can be placed on predicted residual effects. This section will also identify how the uncertainty has been managed so that the effects are not underestimated.

- **Step 6 – Identifying monitoring and follow-up** required to confirm effects predictions and address uncertainty (refer to Section 5.3.2.8 Monitoring and Follow-up).

- **Step 7 – Present a consolidated summary of conclusions and outcomes of the assessment** of residual effects on hydrogeology (refer to Section 5.3.2.9 Conclusions).

This section also describes how the input from engagement influenced the scope of the hydrogeology assessment and information and areas of interest raised by the public, communities of interest, regulators, and First Nations and Métis communities during engagement are summarized in Table 5.3.2-1. Other general areas of interest and questions raised during the engagement that pertain to the hydrogeology assessment (if any) are documented in Appendix 4.0-22 Formal Public Feedback.

Table 5.3.2-1: Summary of Areas of Interest Raised During Engagement Activities that Influenced the Scope of the Hydrogeology Assessment

Area of Interest	How the Area of Interest Was Included in the Assessment
Potential for changes in groundwater quality to affect uses downstream of the ECM	Potential changes in groundwater quality from the NSDF Project were evaluated in the hydrogeology assessment and included potential changes from construction activities (e.g., erosion and blasting activities), changes from treated effluent discharge from the wastewater treatment plant (WWTP), and leakage from the engineered containment mound (ECM) during the post-closure phase following decommissioning of the WWTP.
Treatment of leachate and contaminated water	Leachate and contaminated water from the ECM will be collected and pumped to the WWTP for treatment prior to discharging to the infiltration area.
Potential leakage of leachate from the ECM	Potential leakage of leachate from the ECM during operations will be mitigated through the design and implementation of a composite base liner system, a leachate detection system and a leak collection system. Potential leakage from the ECM during the operations and post-closure phases is considered in the hydrogeology assessment.
Long-term monitoring of groundwater	A long-term monitoring program for the NSDF Project as it relates to groundwater has been developed and is described in the hydrogeology assessment.

5.3.2.2 Valued Components

Valued components refer to environmental features that may be affected by a project and that have been identified to be of concern by the proponent, scientists, government agencies, First Nation and Métis peoples, or the public (the Agency 2014). Hydrogeology is recognized as an important component of the environment that may be affected by the NSDF Project and changes to hydrogeology could, in turn, lead to effects on other VCs selected for assessment. For example, changes to the characteristics of groundwater quality may have a large influence on surface water quality. Subsequently, changes to these characteristics by NSDF Project activities could affect terrestrial and aquatic ecosystem structure and function, human health (including future use [e.g., human intrusion]; Table 5.3.2-2).

Acknowledging that changes to groundwater quantity and quality are considered to be important aspects of the natural and human environment, hydrogeology is referred to as an intermediate component (i.e., it does not have an assessment endpoint). Changes to intermediate component VCs must be understood to facilitate assessment of project interactions. The hydrogeology assessment, therefore, is analyzed for incremental and cumulative (if applicable) changes in the relevant measurement indicators associated with hydrogeology (Table 5.3.2-3). The assessment of hydrogeology focused on predicting changes in the groundwater flow patterns, groundwater table elevations, and concentrations of selected non-radiological substances; radiological parameters are considered in Section 5.7 Ambient Radioactivity. The changes are characterized in terms of magnitude, duration and geographic extent, but are not classified using rankings for effects criteria. The hydrogeology assessment also does not include the assessment of the significance of these changes; rather, results of the analysis of changes in measurement indicators for hydrogeology are provided to other disciplines for inclusion in their assessment (Table 5.3.2-3).

Table 5.3.2-2: Valued Components for the Hydrogeology Assessment

Valued Component	Rationale for Selection
Groundwater quantity and quality	Characteristics of hydrogeology, such as groundwater quantity and quality are important components that interact with other VCs (e.g., hydrology and surface water quality) and if changed by NSDF Project activities could affect terrestrial and aquatic biodiversity, human health (including future use [e.g., human intrusion]).

Table 5.3.2-3: Assessment Endpoints and Measurement Indicators for the Hydrogeology Assessment

Valued Component	Measurement Indicators	Discipline Assessments where Effects on Hydrogeology are Considered
Groundwater quantity	■ Groundwater flow patterns and discharge rates ■ Groundwater table elevations	■ Section 5.4 Surface Water Environment ■ Section 5.5 Aquatic Biodiversity ■ Section 5.6 Terrestrial Biodiversity ■ Section 5.7 Ambient Radioactivity and Ecological Health ■ Section 5.8 Human Health
Groundwater quality	■ Groundwater quality with a focus on changes to the groundwater discharged to Perch Creek watershed	

5.3.2.3 Assessment Boundaries

5.3.2.3.1 Spatial Boundaries

The spatial boundaries selected for the hydrogeology assessment are the same as those defined for geology (see Section 5.3.1.3.1 and Figure 5.3.1-1).

5.3.2.3.2 Temporal Boundaries

Temporal boundaries (i.e., project phases) establish the timeframe during which NSDF Project effects are assessed. The phases identified for the NSDF Project are previously described in Section 5.3.1.3.2. The temporal boundary of the hydrogeology assessment considers all phases of the NSDF Project.

5.3.2.3.3 Assessment Cases

The assessment cases defined for the hydrogeology assessment are the same as those defined for geology (see Section 5.3.1.3.3). Similar to the geology assessment, the hydrogeology assessment includes the Base Case and Application Case. New support infrastructure and research and development facilities will be located within existing disturbed areas on the CRL property. Potential effects from these activities are not expected to interact with hydrolgeology. The end-state plan for the CRL site will be to return lands disturbed by site activities to a condition that is physically stable, and safe in keeping with the land use and landscape of the day. Therefore, decommissioning and environmental restoration activities are anticipated to positively affect hydrogeology. Because RFDs will either have no no interaction or are likely to positively affect hydroegology, an RFD Case is not presented as part of this assessment.There are no potable water wells anticipated to be installed within the RSA during the time up to the end of the post-closure phase. In addition, potable wells would not be anticipated under normal scenario; however, a human intrusion scenario has been evaluated in Section 6.0 Malfunctions and Accidents.

5.3.2.4 Description of the Environment

5.3.2.4.1 Methods

Baseline hydrogeological data were collected from the review of the following reports:

- Radiological Contamination in the South Swamp, 1997 to 2011, CRL Waste Management Area's Environmental Remediation, 3611-121250-REPT-005 Revision 0, January 2015a.
- Radiological Contamination in the East Swamp, 2002 to 2012. 3611-121250-REPT-006. Revision 0. March 2015b.
- Subsurface Radionuclide Migration from the Chemical Pit, CRL Legacy Waste Areas, 3613-121250-REPT-008 Revision 0, October 2014.
- Annual Safety Report, CRL Groundwater Monitoring Program Annual Report for 2014, Chalk River Site Documentation, CRL-509249-ASR-2014 Revision 0, January 2016a.
- Contaminant Migration from Reactor Pit 2, CRL Legacy Waste Areas, 3613-121221-REPT-003 Revision D1, Canadian Nuclear Laboratories, June 2016b.
- Subsurface Geotechnical Survey of the Proposed Near Surface Disposal Facility at Chalk River Laboratories, Chalk River, Ontario, Golder Associates Ltd., June 2016.

The groundwater monitoring program (GWMP) at CRL includes annual and semi-annual water level measurements, sampling and analysis from 180 monitoring wells at 32 sites. Many of the monitoring locations are at the perimeters of various operating areas, and the objective of the program is to monitor the behavior and condition of the facilities. The data from this monitoring program is reported annually in reports such as CRL (2016a). Contaminant migration (i.e., plume) reports such as CNL (2014) and CNL (2016b) are updated on five and 10 year cycles based on data collected as part of the annual program and supplementary investigations. Data contained in these reports has been supplemented with more recent data collected from the NSDF Project site by Golder (2016) and AMEC (2016 and 2017).

A water table elevation map throughout the lower Perch Lake Basin, which includes the NSDF Project Site is shown on Figure 5.3.2-1. For monitoring wells within the NSDF Project site, groundwater levels observed in January 2017 (the most recent set of monitoring data) were used to infer the water table elevation. For monitoring wells outside of the NSDF Project Site the average of historical groundwater elevation (from 1982 to 2017) at each monitoring well was calculated and used to infer a water table elevation.

5.3.2.4.2 Results

5.3.2.4.2.1 Groundwater Flow

Within the Lower Perch Lake Basin, groundwater flow within the overburden is influenced by local topography (and bedrock topography) and is interpreted to be primarily horizontal (CNL 2016b). In the overburden deposits, groundwater flow occurs mainly within the basal sand and gravel, middle sand and upper sand units where present (CNL 2016b). As the silty clay and interstratified silt and sand units that separate these aquifers are not continuous throughout the valley, groundwater elevations, groundwater flow directions and horizontal hydraulic gradients are not differentiated between units. The water table elevation within the NSDF Project site, and throughout the lower Perch Lake Basin (the domain of the groundwater model) is shown on Figure 5.3.2-1. Elevation contours were

generated based on historical information and from more recent information in the NSDF Project Site collected by AMEC in 2017. The extent of the groundwater elevation contours have been limited to the extents of the data available. The available data does not extend beyond the peak of the bedrock ridge to the northeast, and the position of the northeast to southwest groundwater divide cannot be confirmed at this time. However, hydrogeological mapping of the CRL property completed by Raven Beck Environmental Limited (1994), infers the presence of a groundwater divide along this ridge.

The depth the water table within the NSDF Project site was calculated based on groundwater elevation data collected by AMEC in January 2017. Groundwater elevations ranged from 0.22 meters below ground surface (mbgs) (at SH-4) to 12.02 mbgs (at W2-D). The average water table depth was 5.45 mbgs in January 2017. Depth to the water table is generally greatest near the top of the bedrock ridge, and decreases to the south, west, and north, towards the low-lying wetland areas.

Within the NSDF Project site, groundwater flow to the north of the Powerline Cut is generally to the northwest towards the East Swamp. To the south of the Powerline Cut groundwater flow is generally to the southwest and south towards the Perch Lake Swamp and Perch Creek. In the operations areas adjacent to the NSDF Project Site, groundwater flow from Waste Management Area A and Reactor Pit 2 is generally to the south and southwest towards the South Swamp, while groundwater flow from the Chemical Pit is generally to the southeast towards the East Swamp. Within the southern portion of the Perch Lake Basin, groundwater flow is generally towards Perch Lake to the south with a component of flow to the southeast towards Perch Creek.

Hydraulic Gradients

Horizontal hydraulic gradients within the NSDF Project Site were calculated based on groundwater levels collected by AMEC in January 2017 and the groundwater elevation mapping shown in Figure 5.3.2-1. The horizontal hydraulic gradient within the overburden in the northern portion the NSDF Project site was approximately 0.05 metres per metre (m/m) to the northwest (between W2-S and W3). In the southern portion of the NSDF Project site the horizontal hydraulic gradient is approximately 0.05 m/m to the southwest in the overburden between BH-15-8 and SH-5 and approximately 0.07 m/m to the southwest in the bedrock between W4 and BH2-3. It is noted that these gradients are based on a single measurement and likely vary seasonally. Hydrographs prepared by AMEC (2017) indicate that groundwater elevations between November 2016 and January 2017 varied by less than 0.02 m and up to almost 1 m depending on location. Continued monitoring within the NSDF Project site will allow these observations to be refined and for seasonal variability to be quantified.

Vertical hydraulic gradients between the overburden and the bedrock were calculated for monitoring well pairs W2-S/D and BH2-2S/D based on groundwater elevation data collected in January 2017 by AMEC. At W2-S/D a downward vertical gradient of 0.18 m/m from the overburden to the bedrock was calculated, indicating recharging conditions at the topographic high. At BH2-2S/D an upward gradient of 0.03 m/m was calculated, indicating potential for groundwater discharge towards the Perch Creek Swamp.

Average horizontal hydraulic gradients measured in low-lying portions of the Perch Lake Basin range from 0.006 to 0.03 m/m in the area between Reactor Pit 2 and the South Swamp (CNL 2016b). The average horizontal hydraulic gradient is slightly higher, 0.05 m/m, between the South Swamp and Perch Lake Swamp, as measured between AA-183 and PLS-44. In the aquifers underlying the Perch Lake swamp, the average horizontal hydraulic gradients decrease in a southerly direction, from 0.009 m/m (between PLS-44 and PLS-36) to 0.002 m/m (between PLS-32 and PLS-39). Average horizontal hydraulic gradients were found to increase slightly (to 0.006 m/m)

between PLS-39 and the zone of groundwater discharge at Perch Creek. In general, the horizontal hydraulic gradients observed in the low-lying areas of the Basin are lower than those observed at the NSDF Project Site.

Hydraulic Conductivity

Interpretation of hydraulic response testing completed at the NSDF Project site by AMEC and Golder has been summarized in AMEC (2016) and AMEC (2017). Overburden hydraulic conductivity was found to range from 1.4×10^{-7} metres per second (m/s) to 1.6×10^{-5} m/s with a geometric mean of $1.4\text{x}10^{-6}$ m/s based on the results of eight hydraulic response tests. Two additional tests were completed at the bedrock overburden interface, resulting in a slightly higher range of hydraulic conductivity (from 7.2×10^{-6} to 3.1×10^{-5} m/s). A total of 34 hydraulic response tests were completed in the bedrock at 15 borehole locations within the NSDF Project Site. Of these tests, 19 were suitable for analysis and interpretation and the remainder were not analyzable due to slow recovery or instrument malfunction. Hydraulic conductivity was found to range from 2.3×10^{-9} to 1.5×10^{-5} m/s with a geometric mean of 9.2×10^{-8} m/s. As shown on Figure 5.3.2-2, no significant trend in hydraulic conductivity with depth is observed through the tested interval, however, at depths greater than 6 m below the top of the bedrock surface the hydraulic conductivity did not exceed 1×10^{-6} m/s. Overburden porosity was found to range from 0.25 to 0.5 in sand and silty sand intervals, and from 0.25 to 0.3 in sand and gravel intervals (porosity of the bedrock core samples was not reported) (AMEC 2016).

A significant amount of additional hydraulic property information is available based on studies throughout the CRL property in units similar to those encountered at the NSDF Project site. This information is summarized as follows:

- A total of 380 measurements of hydraulic conductivity have been made in this fractured bedrock throughout the CRL property (including the Perch Lake Basin). The geometric mean hydraulic conductivity from these tests was 2.8×10^{-6} m/s, with a one log standard deviation ranging from 3×10^{-12} m/s to 1.0×10^{-4} m/s (CNL 2016b). The fracture porosity of the bedrock is estimated to range from 0.0002 to 0.005 (CNL 2016b).
- A total of 42 single well response tests have been completed in the glacial till and the resulting mean hydraulic conductivity is 1.5×10^{-6} m/s with a one log standard deviation of 4.0×10^{-7} m/s to 5.8×10^{-6} m/s. The results of permeameter tests indicate that vertical hydraulic conductivity may be almost five times lower than these values. However, as only five permeameter tests have been completed and no visible layering is present in the till, this unit is not considered anisotropic (CNL 2016b). Porosity of the glacial till unit ranged from 0.19 to 0.33 (CNL 2016b).
- Testing of the basal sand and gravel has been limited due to the limited extent of the unit (See Section 5.3.1.4.2.2). Sand within this unit is characterized as a moderately to poorly sorted medium sand (CNL 2016b). The mean vertical hydraulic conductivity of the basal sand and gravel is 1.1×10^{-4} m/s based on the results of two permeameter tests. The porosity of this unit has not been measured, but is assumed to be 0.38 (CNL 2016b).
- The laminated nature of the clayey silts in the Perch Lake Basin results in a degree of hydraulic conductivity anisotropy is expected. The vertical mean hydraulic conductivity of this unit, based on the results of 12 permeameter tests, is 5.5×10^{-9} m/s, with a one log standard deviation ranging from 4.6×10^{-10} m/s to 6.5×10^{-8} m/s. The horizontal hydraulic conductivity of this unit has been inferred from the results of six single well response tests. The mean horizontal hydraulic conductivity is 1.3×10^{-7} m/s, with a one log standard deviation ranging from 3.7×10^{-8} m/s to 4.3×10^{-7}m/s. The average porosity of the clayey silt unit is 0.48 (CNL 2016b).

- The vertical mean hydraulic conductivity of the middle sand unit, based on the results of 53 permeameter tests, is 8.7×10^{-6} m/s, with a one log standard deviation ranging from 3.6×10^{-6} m/s to 2.1×10^{-5} m/s. The horizontal hydraulic conductivity of this unit is 7.8×10^{-5} m/s, based on the geometric mean of the results of 13 borehole dilution tests (CNL 2016b). The porosity of this unit is 0.38 (CNL 2016b).
- The vertical mean hydraulic conductivity of the interstratified silt and sand unit, based on the results of 14 permeameter tests, is 3.6×10^{-8} m/s, with a one log standard deviation ranging from 1.76×10^{-9} m/s to 7.5×10^{-7} m/s. Due to the limited thickness of this unit, only one single well response test was completed and the mean horizontal hydraulic conductivity of 1.8×10^{-5} m/s is estimated from the results of grain size analyses (CNL 2016b). The one log standard deviation of horizontal hydraulic conductivity based on the grain size analyses ranges from 5.5×10^{-6} to 8.6×10^{-5} m/s. The measured porosity of this unit is 0.39 (CNL 2016b).
- The vertical mean hydraulic conductivity of the upper sand unit, based on the results of 103 permeameter tests, is 1.4×10^{-5} m/s, with a one log standard deviation ranging from 5.3×10^{-6} m/s to 3.8×10^{-5} m/s. The horizontal hydraulic conductivity of this unit is 4.8×10^{-5} m/s, based on the geometric mean of the results of 38 borehole dilution tests (CNL 2016b). The porosity of this unit is 0.38 (CNL 2016b).

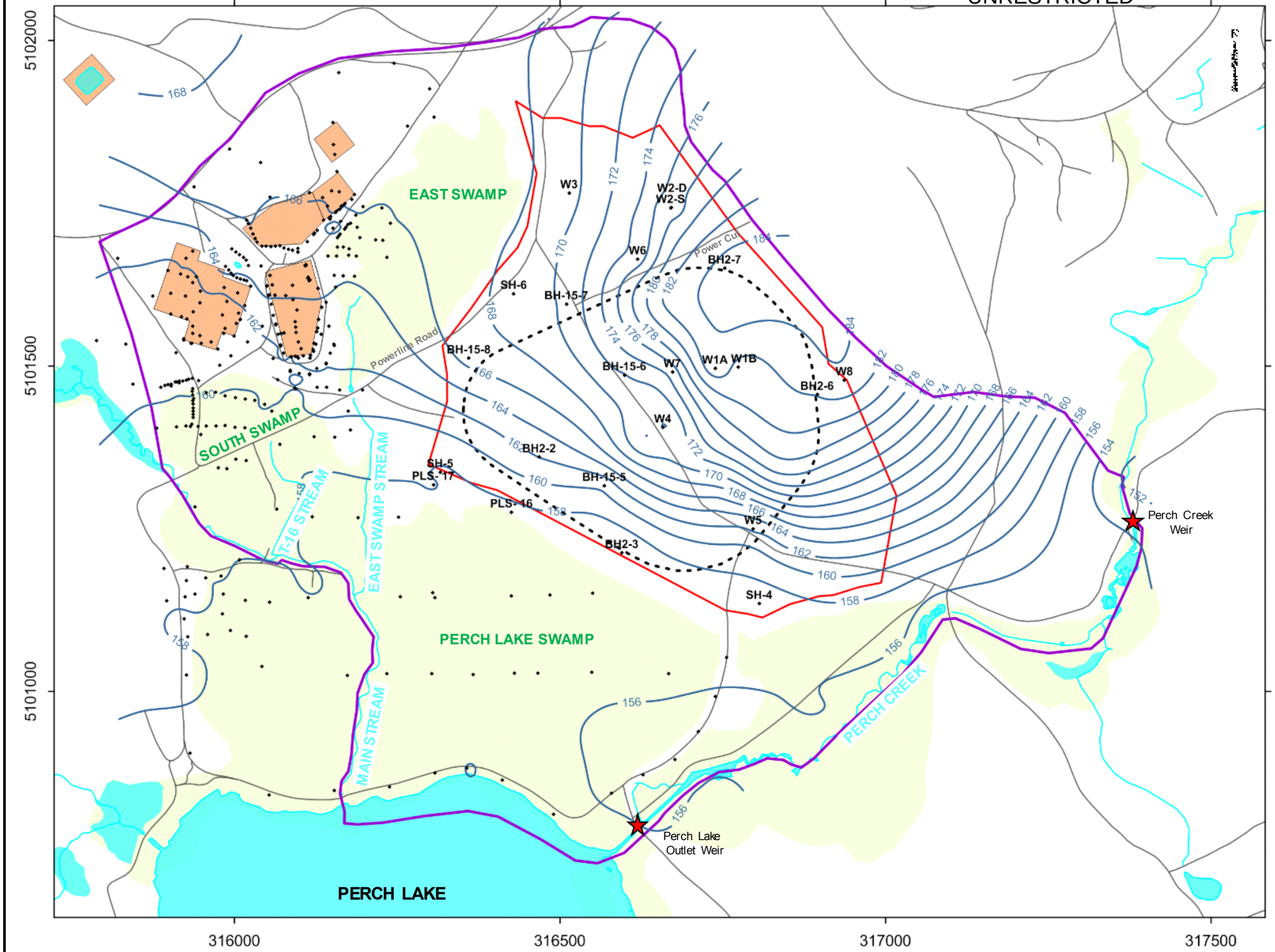
The hydraulic conductivity of the bedrock at the NSDF Project site is at the higher end of the range observed throughout the CRL Property. Testing at the NSDF Project Site was limited to the upper 20 m of the bedrock unit, while the range observed throughout the CRL property includes tests up to 50 m below the top of the bedrock unit. These results indicate a likely decrease in hydraulic conductivity with depth in bedrock. Overburden hydraulic conductivity at the NSDF Project site is consistent with the range in glacial till and sand units observed elsewhere on the CRL property.

Groundwater Recharge and Discharge

The bedrock ridges and topographic highs at the eastern and western boundaries of the Perch Lake Basin act as groundwater (and surface water) divides. A groundwater divide is also present to the north, along Plant Road (CNL 2016b). The shallow groundwater flow system is expected to be recharged through precipitation at these topographic highs. Groundwater discharge generally occurs at the surface water features within the low-lying portions of the Perch Lake Basin. Groundwater springs are observed in the East Swamp stream to the north of Powerline Road and in Perch Creek, downstream of the Perch Lake Outlet Weir. Groundwater discharge to the East Swamp stream to the north of Powerline Road was observed to range from 25 cubic metres per day (m^3/d) to 770 m^3/d during low-flow periods (Golder 2017). Groundwater discharge to Perch Creek during low-flow periods is estimated to be approximately 790 m^3/d based on the difference in average flow measurements between the Perch Lake Outlet Weir and the Perch Creek weir (shown on Figure 5.3.1-4). It is noted that the East Swamp Stream south of Powerline Road and the T-16 Stream act sources of groundwater recharge to the upper sand unit, however, no quantitative estimates are available for these areas.

Within the NSDF Project site, a groundwater divide is likely present in the vicinity of the Powerline Cut. Groundwater to the north of this road likely discharges to surface water within the East Swamp, while groundwater to the south of this road likely discharges to the surface water within Perch Lake Swamp (or to Perch Creek for the southern portion of the NSDF Project site). No areas of groundwater discharge (i.e., seeps or springs) were noted within the observable portions of the NSDF Project site by AMEC (2016)

Surface water within the East Swamp receives groundwater discharge from the Chemical Pit (CNL, 2014) and to a lesser degree from Reactor Pit 2 (CNL 2015b). Groundwater flow from the Chemical Pit to the East Swamp follows a relatively short groundwater flow path, with a travel time of approximately four months (CNL 2015b). Groundwater from Waste Management Area A, and the most of Reactor Pit 2 discharges to surface water in the South Swamp.



LEGEND

- Model Boundary
- ECM Location
- Roads
- NSDF Project Site
- Stream
- Waterbody
- Wetland
- Waste Management Area
- Geological Surface Data Point
- NSDF Project Data Point
- Groundwater Elevation Contour (m ASL)

NOT TO SCALE

REFERENCE(S)

1. PERCH LAKE SUB-BASINS OBTAINED FROM E. ROBERTSON & P.J. BARRY (1985) THE WATER AND ENERGY BALANCES OF PERCH LAKE (1969–1980), ATMOSPHERE-OCEAN, 23:3, 238-253, DOI: 10.1080/07055900.1985.96492270)

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
GROUNDWATER TABLE ELEVATION FOR THE NSDF PROJECT SITE

CONSULTANT

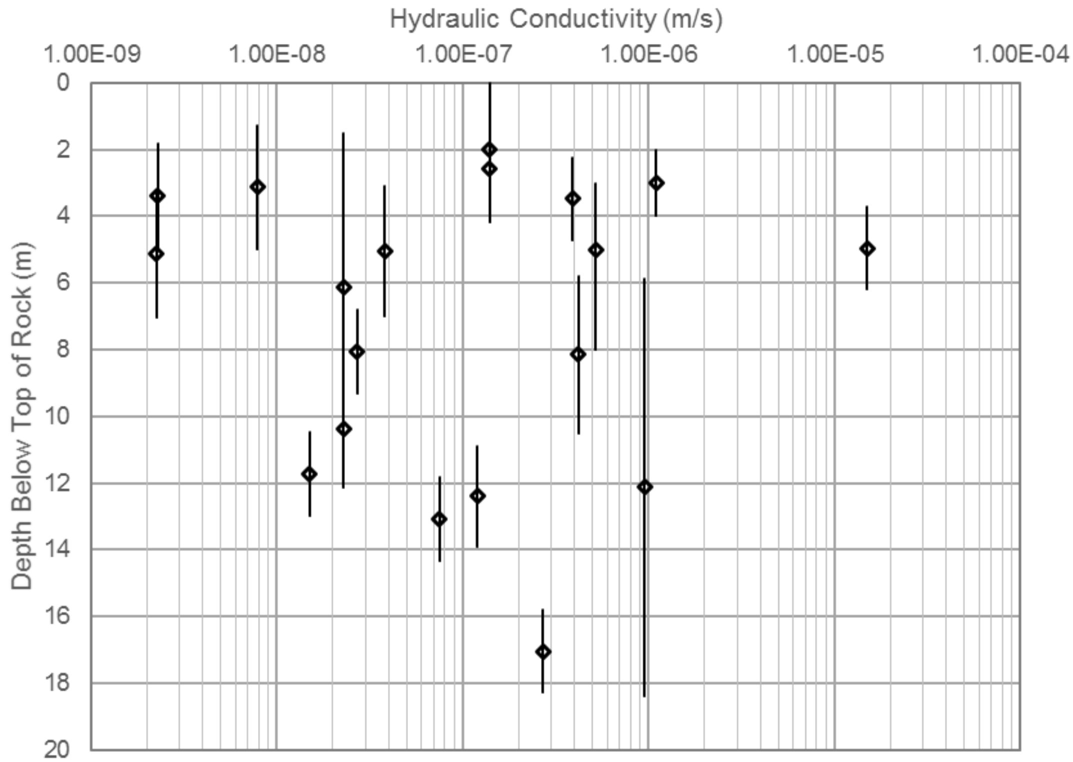
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	NFB/MIB
PREPARED	SO/JR
REVIEWED	JL
APPROVED	GVA

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0011	0.0	5.3.2-1

S:\Clients\Canadian_Nuclear_Laboratories\NSDF\99_PROJ\1547525_NSDF_EIS\40_PROD\0009_EIS_Section_5\Section_5.3_Geology_Hydrogeology\1547525-0009-CH-0015.mxd

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm



LEGEND

Top of Tested Interval

Mid-Point of Tested Interval

Bottom of Tested Interval

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
BEDROCK HYDROLIC CONDUCTIVITY DISTRIBUTION FOR THE NSDF PROJECT SITE

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	NFB/MIB
PREPARED	SO/JR
REVIEWED	JL
APPROVED	GVA

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0011	0.0	**5.3.2-2**

5.3.2.4.2.2 Groundwater Quality

Bedrock groundwater quality throughout the CRL Property has been characterized through the sampling of a series of deep bedrock boreholes (as documented in AECL 2010 and King-Sharpe et al. 2016). It was found that variations in bedrock groundwater quality with depth are generally consistent throughout the CRL Property. Shallow groundwater, to depths of up to 100 m, is dominated by sodium and bicarbonate, with pH values generally between 7 and 8. Deeper groundwater (between depths of 100 and 900 m) is consistently alkaline with a pH value of about 9. Concentrations of sodium and chloride were found to increase with depth; however, concentrations of these parameters are relatively low in comparison to deep groundwater in other parts of the Canadian Shield, with total dissolved solids concentrations generally below 200 milligrams per litre (mg/L) (King-Sharpe et al. 2016). A profile of chloride concentrations in borehole CR9 indicated three distinct zones: a shallow zone (in the upper 300 m) with chloride concentrations ranging from 10 to 60 mg/L, a middle zone (from 300 to 500 m) with chloride concentrations ranging from 150 to 200 mg/L, and a deep zone (from 500 to 700 m) with chloride concentrations ranging from 1,000 to 1,600 mg/L indicating slightly brackish conditions (AECL 2010). It was concluded that these relatively dilute waters are likely related to recharge of meteoric waters at the end of the last glaciation (King-Sharpe et al. 2016). Based on results of routine monitoring conducted since 1997 for the GWMP (described above) (CNL 2016a) as well as detailed plume monitoring downgradient of the Liquid Dispersal Areas (LDAs) including Chemical Pit (CNL 2014), Reactor Pit 2, Reactor Pit 1 and Laundry Pit, it can be concluded that these facilities do not make a significant contribution to inorganic parameter concentrations in the groundwater (CNL 2016a).

Downgradient of the Chemical Pit, elevated concentrations of mercury (generally less than 2 micrograms per litre [µg/L]), lead (generally less than 10 µg/L) and uranium (between 10 and 20 µg/L) have been observed in groundwater (CNL 2014). Elevated chloride concentrations attributed to road salt effects have been observed in groundwater downgradient of Waste Management Area A and Reactor Pit 2. Downgradient of these facilities concentrations are on the order of 500 to 1,000 mg/L (CNL 2016b). No elevated concentrations of mercury or other heavy metals have been detected downgradient of Waste Management Area A or Reactor Pit 2.

Volatile organic compounds (VOCs) have been detected downgradient of Waste Management Area A at concentrations generally below 10 µg/L; however, the most prevalent VOC 1,1,2,2-Tetrachloroethane has been detected at concentrations as high as 50 µg/L. With the exception of chloroform (and only for a brief period), no volatile organic compounds or extractable organic compounds were detected in groundwater downgradient of Reactor Pit 2 between 1997 and 2012 (CNL 2016b). No polycyclic aromatic hydrocarbons (PCBs), dioxans, or furans were present in the groundwater plumes from Waste Management Area A or Reactor Pit 2 (CNL 2015a). PCBs were detected at downgradient of the Chemical Pit at concentrations up to 0.7 µg/L (CNL, 2014). Trace detections of dioxans and furans were also noted downgradient of the Chemical Pit in 2014 (CNL 2016a)

The highest concentrations and widest variety of radioactive contaminants in groundwater on the CRL property are located downgradient of the Chemical Pit (CNL, 2016a). Total beta activity associated with strontium-90 in groundwater between the Chemical Pit and the East Swamp is on the order of 10,000 to 70,000 Becquerels per litre (Bq/L). Gross alpha, cesium-137 and cobalt-60 in groundwater are also elevated (CNL 2016a). Characterization of the groundwater plume from the Chemical Pit has also included the sampling of pore water from the East Swamp (indicative of groundwater discharging to the surface water). Gross alpha, total beta, and strontium-90 activities were found to range from <3 to <8 Bq/L, 230 to 4,900 Bq/L, and 120 to 2,960 Bq/L respectively (CNL, 2015b). Downgradient of Waste Management Area A total beta activity in groundwater was

generally between 3,000 and 10,000 Bq/L with a peak of 30,000 Bq/L. Downgradient of Reactor Pit 2 total beta activity in groundwater was generally between 2,000 and 15,000 Bq/L with a peak of 22,100 Bq/L (CNL, 2015a).

Within the NSDF Project site groundwater samples were collected from BH15-7 and BH15-8 in May 2016 (Golder 2016). Samples were analysed for a variety of parameters including general chemistry and metals. The results from the analyses of these samples show a generally neutral pH and a low concentration of dissolved solids. Chloride levels of 53.7 and 46.6 mg/L might reflect the past use of deicing salts along East Mattawa Road; however the concentrations are only marginally above those typically encountered in undeveloped lands in the area. With the exception of manganese at BH15-7, results were below the Ontario Drinking Water Quality Standards, Objectives, and Guidelines (ODWQS, MOECC 2006). Manganese is naturally occurring in groundwater, and the ODWQS is related to aesthetics and not health.

Further groundwater sampling at the NSDF Project site was completed by AMEC in October and December 2016 (AMEC, 2016 and AMEC, 2017) (Figure 5.3.2-3) . Samples were analysed for a variety of parameters including general chemical parameters, metals, VOCs, and radiological components. Bromodichloromethane was detected at three locations and chloroform was detected at seven locations within the NSDF Project site in October 2016 (AMEC 2016). These parameters are likely associated with residual drilling fluids present in the formation; however, further monitoring should confirm this interpretation. VOCs were not analysed in samples collected in December 2016. Chloride concentrations were found to range from 1.9 to 54 mg/L indicating limited road salt impacts on the NSDF Project Site. Tritium, gross alpha, and total beta activities were found to range from < 64 to 155 Bq/L, <0.009 to 0.552 Bq/L, and <0.01 to 1.06 Bq/L respectively. These results are slightly elevated in comparison to ambient radiological conditions in groundwater observed near the NSDF Project site (see section 5.7.4.6 Radioactivity in Groundwater). It is noted that these ranges are based on only two monitoring events for the NSDF Project site.

LEGEND

- GROUNDWATER MONITORING WELL (AMEC 2016)
- TRANSMISSION LINE
- RIVER/STREAM
- WATERBODY
- WETLAND
- WOODED AREA
- CRL MAIN CAMPUS
- NSDF PROJECT SITE
- WASTE MANAGEMENT AREA (WMA)[1]
- 30 m WETLAND SETBACK
- SURFACE WATER MANAGEMENT POND
- STOCKPILE AREA

100 0 100 200

1:5,000 METRES

NOTE(S)

1. LIQUID DISPOSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.

REFERENCE(S)

1. BASEDATA MNRF 2016 AND CANVEC 2016
2. IMAGERY:
3. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18N

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
LOCATION OF GROUNDWATER MONITORING WELLS INSTALLED IN 2016

CONSULTANT

Golder Associates

YYYY-MM-DD	2017-03-03
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	MM
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.3.2-3

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm

This page intentionally left blank

5.3.2.5 Project Interactions and Mitigation

5.3.2.5.1 Methods

This section describes the process by which interactions between NSDF Project components and activities and groundwater quantity and quality were identified and evaluated. Potential effect pathways are identified and mitigation developed to eliminate and/or reduce effects is presented. A pathways analysis is then used to focus the assessment on key interactions between the NSDF Project and the environment by evaluating the different effect pathways to determine if, after incorporation of mitigation, there is still potential to cause residual effects. Where effects will be adequately mitigated and are not forwarded for further analysis (i.e., secondary pathways, or where mitigation will remove the pathway altogether), the reasons for concluding the assessment at this stage are articulated. Primary pathways that may lead to residual effects after incorporation of mitigation are further characterized in subsequent subsections of the assessment. As such, this section helps to focus the remainder of the assessment on those interactions (effects pathways) likely to result in residual adverse effects.

The first part of the analysis was to identify the potential effects pathways for all phases of the NSDF Project. The next step in the analysis was the development of environmental design features and mitigation practices that could be incorporated into the NSDF Project to eliminate and/or reduce adverse effects to hydrogeology. Environmental design features included Project design elements, environmental best practices and management policies and procedures. Environmental design features and mitigation were developed through an iterative process between the Project's engineering and environmental teams, combined with input from Project-specific or regional engagement with other interested parties. The design features and/or mitigation activities were selected considering their effectiveness for implementation and maintenance and their appropriateness within the context of the identified effect pathways.

After incorporation of mitigation, potential pathways were evaluated into the following categories using scientific knowledge, logic, experience with similar developments and the effectiveness of environmental design features and mitigation:

- **No pathway –** pathway is removed by environmental design features or mitigation such that the Project would not be expected to result in a measurable environmental change relative to Base Case values and therefore would have no residual effects to hydrogeology.
- **Secondary pathway –** the pathway could result in a measurable minor environmental change, but would have a negligible residual effect on hydrogeology relative to Base Case and/or guideline values and is not expected to contribute cumulatively to other Project effects or to the effects of other past, present or reasonably foreseeable developments to cause a significant effect.
- **Primary pathway –** the pathway is likely to result in an environmental change relative to the Base Case and/or guideline values that could contribute to residual effects to hydrogeology.

Environmental design features and mitigation that have been or could be incorporated into the Project to eliminate and/or reduce adverse effects were considered. Potential pathways that were completely removed due to implementation of environmental design or mitigation were not assessed further. Pathways that were assessed to be secondary and demonstrated to have a negligible residual effect to hydrogeology through simple qualitative or semi-quantitative evaluation of the pathway were also not advanced for further assessment. Primary pathways were carried forward for more detailed quantitative and qualitative effects analysis to characterize the residual effects of the Project.

5.3.2.5.2 Results

Pathways through which all stages of the Project may interact with and result in changes to measurement indicators for hydrogeology is provided in Table 5.3.2-4.

Table 5.3.2-4: Pathways Analysis for the Hydrogeology Valued Components

Project Activity	Effects Pathways	Management Practices and Mitigation	Pathway Assessment
■ Project activities during the construction phase: ▪ Site Preparation ▪ Construction of the ECM ▪ Development of surface water management structures ▪ Construction of the WWTP and other support facilities ▪ On-site road and access development	The construction of the NSDF Project will physically alter groundwater levels and flows	■ The NSDF Project footprint has been designed to limit disturbance to the natural environment. ■ Discharge of treated effluent to the exfiltration gallery area will help to reduce water loss from the hydrogeological system.	Primary

Table 5.3.2-4: Pathways Analysis for the Hydrogeology Valued Components

Project Activity	Effects Pathways	Management Practices and Mitigation	Pathway Assessment
■ Project activities during the construction phase (as listed above) ■ Project activities during the operation phase: ▪ Staged development of disposal cells in the ECM ▪ On-site transportation of waste and placement in the ECM ▪ Progressive closure of disposal cells and installation of cover ▪ Operation of the WWTP ▪ Existing presence of fencing around perimeter of ECM ▪ Surface water management ▪ Domestic waste (solid and liquid) management; and, ▪ Routine operational management and monitoring activities.	Surface water runoff from the NSDF site can contain contaminants, which can cause changes to groundwater quality	■ A Surface Water Management Plan will be implemented. ■ An Erosion and Sediment Control Plan has been developed based on the Erosion and Sediment Control Guidelines for Urban Construction. ■ The target surface water quality objective is provided by the Ontario Ministry of the Environment and Climate Change (MOECC, formerly Ministry of the Environment [MOE]) in Stormwater Management Planning and Design Manual (MOECC 2003). ■ Surface water from all external areas will be conveyed by ditches, swales and culverts to surface water management ponds that will address water quality and water quantity criteria established for the wetland receiving waters and, ultimately, Perch Creek. ■ The surface water management ponds are designed to address erosion and sediment control concerns during construction by providing interim sediment control and by providing water quality/quantity controls during operations, closure, and post-closure. ■ The current surface water management pond footprints reflect the overall storage required to control post-closure flows to predevelopment levels for the 2-year through to 100-year rainfall events at the site. This volume also contains the storage required for sediment control during construction and water quality control during operations. ■ For each surface water management pond, the water level will be sampled continuously from May through November inclusive to estimate the inflow and outflow of each pond. ■ The outlet water quality will be sampled twice annually as a composite grab sample during a minimum 1 hour rainfall of greater than 30 millimetres (mm) to determine if there is any contact surface	No Linkage

Table 5.3.2-4: Pathways Analysis for the Hydrogeology Valued Components

Project Activity	Effects Pathways	Management Practices and Mitigation	Pathway Assessment
■ Project activities during the operations phase	■ Leakage of leachate from the ECM may affect groundwater quality during operations	■ The composite base liner design will include both primary and secondary liner systems. ■ The primary liner will include a leachate collection system with the secondary liner housing a leak detection system. ■ The high-density polyethylene (HDPE) geomembrane was selected as it is compatible with the leachate generated by the waste and will achieve a long service life. ■ The composite base liner system will include an underlying compacted clay liner to supplement the primary and secondary liner system.	No linkage

Table 5.3.2-4: Pathways Analysis for the Hydrogeology Valued Components

Project Activity	Effects Pathways	Management Practices and Mitigation	Pathway Assessment
■ Project activities during the operations and closure phases: ▪ Surface water management ▪ Operation of the WWTP ▪ Discharge of treated effluent from the WWTP	■ Discharge of treated effluent from the WWTP to the East Swamp Wetland can cause changes to groundwater quality.	■ The strategy for wastewater treatment is based on optimizing public and environmental protection by defining an approach to wastewater treatment that uses best demonstrated available technology that is economically achievable (BDATEA), and capable of meeting regulatory requirements. ■ The treatment target for effluent is the CRL Acceptability Criteria for Routine and Non Routine Discharge of Liquids to Stormwaters.The effluent requirement for treated wastewater is the CRL Acceptability Criteria for Routine and Non Routine Discharge of Liquids to Stormwaters. ■ Treated effluent will be sampled and confirmed that it meets guidelines treatment targets before release to East Swamp Wetland ■ An exfiltration gallery is proposed at the discharge outlet to promote the exfiltration of treated water into the local groundwater regime. ■ Appropriate procedures to identify emergency spill occurrences and response, as well as appropriate response to non-contact surface water or leachate contamination will also be implemented as described in the Operations and Maintenance Plan and Contingency Plan	Secondary

Table 5.3.2-4: Pathways Analysis for the Hydrogeology Valued Components

Project Activity	Effects Pathways	Management Practices and Mitigation	Pathway Assessment
	■ Leakage of leachate from the ECM may affect groundwater quality during operations and closure phase.	■ Design of the ECM includes base contours that have been developed using a herringbone pattern with ridges and valleys to promote leachate transport to the leachate collection system for removal. ■ The base liner design include both primary and secondary liner systems that are designed to have redundancy in case of premature failure and are a combination of natural and synthetic barrier systems. ■ The HDPE geomembrane for the liner was selected as it is compatible with the leachate generated by the waste and will achieve a long service life. ■ The base liner system will include an underlying compacted clay liner to supplement the primary and secondary liner system. ■ The leachate collection and monitoring system design will provide accessible access points for monitoring, inspections, maintenance, repairs and replacements. ■ Monitoring of the treated effluent discharge will be completed in accordance with CNL's Management and Monitoring of Emissions Procedure.	No Linkage
■ Project activities during the closure and post-closure phases: ▪ Maintenance of fencing around perimeter of ECM ▪ Installation of final ECM cover, restoration and grading of SSA ■ On-going long-term performance monitoring, transfer of NSDF Project into Institutional Control	■ Leakage of leachate from the ECM during the post-closure phase (i.e., after Year 2400) from liner and cover failure as a result of normal evolution can cause changes to groundwater quality.	■ The final cover system will be constructed to promote the shedding of surface water to mitigate infiltration into the mound, and minimize leachate generation. ■ The cover system design incorporates a series of shallow, trapezoidal, riprap-lined drainage channels that are designed to convey water at low velocity. ■ The perimeter road ditch will route the runoff around the ECM perimeter to minimize ponding of water into the closed ECM, erosion of the cover and underlying waste materials, destabilization of the ECM structure, and damage to access roads. ■ The ECM final grading and drainage plan also includes collection ditches along the top of the ECM berm road to collect side slope drainage.	Primary

5.3.2.5.2.1 No Linkage Pathways

The following pathways were assessed as having no measurable environmental change and hence, no linkage to residual effects on hydrogeology VCs.

Surface water runoff from the NSDF site can contain contaminants, which can cause changes to groundwater quality.

The surface water management ponds are designed to address erosion and sediment control concerns during construction by providing interim sediment control and by providing water quality/quantity controls during operations, closure, and post-closure. The current surface water management pond footprints reflect the overall storage required to control post-closure flows to predevelopment levels for the 2-year through to 100-year rainfall events at the site. This volume also contains the storage required for sediment control during construction and water quality control during operations. The target surface water quality objective is provided by the Ministry of Environment and Climate Change (MOECC) in Stormwater Management Planning and Design Manual (MOECC 2003), which reports a 60% total suspended solids (TSS) removal that provides a basic water quality treatment for discharge to the receiving wetland.

During the construction phase, erosion and sediment control measures will be in place to mitigate the effects of soil erosion and sediment transport. The measures include the use of erosion control blankets, as needed, to control erosion on steep slopes, check dams in ditches and swales, and the three proposed surface water management ponds that will be constructed to serve as interim sediment control facilities during construction, and then as stormwater management facilities during the operations, expansion and post-closure periods. Erosion and sediment control practices (e.g., silt fences, runoff management) applicable to the region and already in place at the CRL property (i.e., CNL's Management of Land and Habitat Procedure) will be used around disturbed areas, where appropriate.

Site operations include surface water management for the ECM and all external areas. Surface water from all external areas will be conveyed by ditches, swales and culverts to surface water management ponds that will address water quality and water quantity criteria established for the wetland receiving waters and, ultimately, Perch Creek. Contact surface water drainage from the active cells of the ECM will be to the WWTP. Non-contact surface water drainage from completed cells and yet-to-be-activated cells will be directed either by gravity to the external surface water management system or to temporary holding ponds within the ECM, or then pumped to the three surface water management ponds. There will be a need to address pre-treatment of surface water run-off from the active cells prior to conveyance to the WWTP and a need to establish conveyance mechanisms (gravity and pumping) from the interior of the ECM to the surface water management ponds.

Facility inspections will be completed twice annually to confirm that inlets and outlets are clear of debris and to confirm that there are no major erosion issues at the inlet or outlet. As well, the integrity of berms and outlet structures will be confirmed by visual inspections (e.g., to identify any animal burrowing activity or active soil erosion). Inspections will also include an annual sediment level monitoring component within each pond to identify sediment accumulation rates that may require clean-out requirements. If necessary, pond sediment will be extracted by excavation equipment and will be disposed of based on sediment sampling, testing, and classification according to MOECC standards, or stockpiled, de-watered and re-used on-site for ECM cover operations. Sediment removal will follow procedures identified in the Stormwater Management Planning and Design Manual (MOECC 2003).

The implementation of these mitigation measures will reduce the potential for changes to soil, water and vegetation quality from surface water runoff from the NSDF site. As such, this pathway was determined to have no linkage to effects on the abundance of wildlife habitat, and survival and reproduction of wildlife and is not anticipated to affect the maintenance of self-sustaining and ecologically effective wildlife populations that overlap the RSA.

Leakage of leachate from the ECM may affect groundwater quality during operations.

Design of the ECM includes base contours that have been developed using a herringbone pattern with ridges and valleys to promote leachate transport to the leachate collection system for removal. The base liner design include both primary and secondary liner systems that are designed to have redundancy in case of premature failure and are a combination of natural and synthetic barrier systems. The primary liner will include a leachate collection system with the secondary liner housing a leak detection system. The composite base liner will contain perforated high-density polyethylene (HDPE) collection and monitoring pipes. The HDPE geomembrane was selected as it is compatible with the leachate generated by the waste and is expected to perform as an effective hydraulic and diffusion barrier over the 500-year design life (see Section 3.5.2.4). The base liner system will include an underlying compacted clay liner to supplement the primary and secondary liner system. The leachate collection and monitoring system design will provide accessible access points for monitoring, inspections, maintenance, repairs and replacements.

The primary liner system will contain the leachate collection system, and will convey leachate to a single collection point for removal from the mound, for transfer to the WWTP for treatment. The primary liner system serves as the primary source of protection for the natural environment below the mound from leachate migration, and will maintain a maximum depth of leachate on the geomembrane liner of less than or equal to 300 mm. The secondary liner system will contain the leak detection system, which will be used to detect leaks in the unlikely event that the primary liner system fails. The secondary liner will also protect the natural environment from leachate migration if the primary liner system fails. Leachate collected by the leachate collection system will be pumped to the onsite WWTP for treatment.

Designed berms consist of three main geotechnical elements, or layers, each contributing to the soundness and integrity of the berm itself and the whole ECM. A Slope Stability Analysis was completed to provide the information needed to support the design of the base slopes, sidewalls, and side slopes of the ECM. The Slope Stability Analysis addresses the range of anticipated loading conditions, under both short-term and long-term scenarios, to confirm that the slope designs will satisfy minimum factor-of-safety requirements for stability. Size and shape of the berms and each of the elements and layers were determined using a seismic design basis.

The implementation of the above mitigation will limit the potential for changes to groundwater quality from the NSDF site. As such, this pathway is determined to have no linkage to effects on hydrogeology.

5.3.2.5.2.2 Secondary Pathways

The following pathways were assessed as potentially having a measurable minor environmental change, but negligible residual effect on the hydrogeology VCs relative to Base Case.

- **Discharge of treated effluent from the WWTP to the East Swamp Wetland can cause changes to groundwater quality.**

The WWTP for the NSDF Project will be a new, stand-alone facility with a new discharge point. The WWTP will treat leachate generated in the ECM during operations and the closure periods. The strategy for wastewater treatment is based on optimizing public and environmental protection by defining an approach to wastewater treatment that uses best demonstrated available technology that is economically achievable (BDATEA), and capable of meeting regulatory requirements.

The chemical and radionuclide concentrations in leachate are calculated using a partitioning model that assumes that the ratio of the contaminant concentration in the solid phase to the contaminant concentration in the leachate is constant. These factors conservatively estimate the leachate characteristics. The radionuclide concentrations in wastewater are a combination of the leachate concentrations and the leachate volume, combined with the contact water and decontamination volumes. The contact water is assumed to have very low radionuclide concentrations because of the effects of daily ECM cover and water management practices within the disposal cell. Decontamination water is assumed to have the same radiological and chemical characteristics as the wastewater from the ECM. In the absence of quantitative information, non-radioactive waste constituents were developed from, information gathered from other sites and the expected characteristics of wastes to be disposed of in the NSDF. These values present a reasonable and conservative estimate of concentrations in wastewater such that the WWTP design is capable of treating wastewater to meet site-specific treatment targets.

Treated effluent will be sampled and confirmed that it meets treatment targets before release to East Swamp Wetland. Treated effluent from the WWTP will be released to an exfiltration gallery promote the exfiltration of treated water into the local groundwater regime.

5.3.2.5.2.3 Primary Pathways

Primary pathways identified for hydrogeology and that are evaluted in the residual effects analysis (Section 5.3.2.6) include:

- the construction of the NSDF Project will physically alter groundwater levels and flows; and
- leakage of leachate from the ECM during the post-closure phase (i.e., after Year 2400) from liner and cover failure as a result of normal evolution can cause changes to groundwater quality.

5.3.2.6 Residual Effects Analysis

5.3.2.6.1 Groundwater Flow

5.3.2.6.1.1 Methods

Residual effects from the Application Case are evaluated based on the results of hydrogeological modelling. The Hydrogeological modelling was completed to estimate the groundwater flow pathways from the ECM, and the rates of groundwater flow from the NSDF Project site to downstream receptors. This was accomplished by constructing a groundwater flow model based on the conceptual model and calibrating it to the existing conditions. Calibration involved an iterative process where steady-state model runs were completed with adjustments to the model input parameters (within acceptable ranges) until model results provided an acceptable match to observed conditions (groundwater elevations, groundwater flow directions, baseflow estimates, and advective flow paths from the Reactor Pit 2 source area). After an acceptable model calibration was achieved, the calibrated model was then modified to represent the NSDF Project site under operations and post-closure conditions and steady-state simulations were completed to evaluate the changes in groundwater flow patterns and water table elevations from the NSDF Project site.

MODFLOW-2005 (Harbaugh 2005) was used to complete the simulations. Visual MODFLOW® (Version 4.6.0.156) was used as the numeric flow engine for the simulations and the MODFLOW-NWT solver was used to solve the groundwater flow equations (Niswonger et al. 2011). MODPATH (Pollock 1989), a companion code to MODFLOW, was used to complete the particle tracking analyses necessary to illustrate the flow paths from the WWTP and ECM. Details of the conceptual model development, modelling approach, model extent and discretization, boundary conditions, hydrostratigraphy and parameterization and model calibration are reported in Golder (2017).

Three operations phase scenarios were evaluated with the model as follows:

- Operations Scenario A – Development of Cells 1 through 3 (Cells 1 and 2 are closed and Cell 3 is active).
- Operations Scenario B – Development of Cells 1 through 8 (Cells 1 through 7 are closed and Cell 8 is active).
- Operations Scenario C – Full development of the ECM (Cells 1 through 9 are closed and Cell 10 is active).

In all operations scenarios zero infiltration was applied over the footprint of the open and closed cells (precipitation is being collected via the liner) (Golder, 2017). Water collected within footprint of the open cell is sent to the WWTP and discharged in the model as surficial recharge at the WWTP outfall location. Runoff is collected from the closed cells and an equivalent volume is applied as recharge in the model to the surface water management ponds outfall areas.

Three scenarios were evaluated using the model under post-closure conditions as summarized below:

- **Post-closure – Engineered Cover Intact:** An engineered cover is in place above the waste in the ECM, extending to the crest of the berm surrounding the facility. In this area zero recharge is applied in the groundwater flow model. Runoff that occurs from precipitation falling on the engineered cover is directed to the storm water management (SWM) ponds. It is assumed that during the post-closure period the pond liners will no longer be effective, and the runoff collecting in the ponds will infiltrate through the bottom of the pond.
- **Post-closure – Engineered Cover Compromised:** The engineered cover is assumed to be compromised resulting in infiltration through the mound into the waste materials. The base liner is assumed to remain intact resulting in a “bathtub” effect with spillover along the low point of the base liner, located in the southern portion of the ECM. For this scenario the surface runoff from the ECM was assumed to have a negligible affect on local groundwater conditions, and no additional water was applied beyond the natural surficial recharge.
- **Post-closure – Engineered Cover and Liner Compromised:** Both the engineered cover and liner are assumed to be compromised resulting in infiltration through the waste materials and into the underlying geological materials.

5.3.2.6.1.2 Application Case Results

The main findings of the operations and post-closure phase base case simulations are discussed in Golder (2017) and summarized below:

- For the operations scenarios (where the WWTP is operational) groundwater particles released from the WWTP outfall area travel towards the west, ultimately discharging at the East Swamp. The majority of the particles discharge to the East Swamp immediately downgradient from the WWTP outflow area, whereas the remaining particles follow a deeper flow path and discharge at the East Swamp Stream after approximately 3 years (Figures 4.3 through 4.5 in Golder 2017).
- For Operations Scenarios B and C and the Post-Closure Scenario with an intact engineered cover (i.e., the scenarios where runoff is directed to the surface water management ponds) there were localized rises in the simulated water table in the vicinity of the surface water management ponds. For Operations Scenario C the maximum rise was approximately 1 m, and was limited to the northern surface water management pond outfall area. For the Post-Closure Scenario with an intact engineered cover the rise in groundwater elevation was up to 2 m (Figure 4.6 in Golder 2017).
- Collection of water (infiltration and/or runoff) over the ECM footprint resulted in a lowering of the water table for all simulations, though this was generally limited to the local footprint of the ECM and the area to the north east of the ECM (i.e., towards the groundwater flow divide). The maximum simulated reduction in groundwater elevation occurred over the central and eastern portions of the ECM, to a maximum of approximately 6 m. The magnitude and distribution of water table lowering was approximately equal for Operations Scenarios B and C and the Post-Closure scenarios with intact liners. For Operations Scenario A the change in simulated water table elevation was less extensive and reached a maximum of approximately 2 m (Figures 4.3 through 4.7 in Golder 2017). For the Post-Closure Scenario where the cover and liner were assumed to be compromised the recharge applied over the ECM footprint (300 millimeters per year [mm/yr]) was greater than the recharge applied over the same area in the calibrated model, and therefore resulted in a rise in the water table of up to approximately 3.5 m (see Figure 4.8 in Goler 2017).

- For the Post-closure Scenario where the engineered cover was assumed to be compromised the groundwater particles follow a flow path towards the south-southeast, with the majority of particles discharging to Perch Creek (a small portion of the particles released from the westernmost and easternmost spillover area locations discharged at surface to the Perch Lake Swamp). Groundwater travel times between the spillover and Perch Creek for the majority of particles ranged from approximately 7 years to 10 years (Figure 4.7 in Golder 2017). Based on the position of the water table the groundwater particles began at the spillover location travelling through the till unit, then transitioned to the travelling through the upper sand units before reaching their ultimate discharge location. An example of a conservative (i.e., early-arriving) groundwater particle is illustrated on Figure 4.7 (in Golder 2017; see the path with points marked from A through D). At this location the groundwater particle reaches Perch Creek in approximately 5 years, and has a groundwater velocity ranging from 0.12 meters per day (m/d) to 0.17 m/d depending on its position in the groundwater flow path.
- A similar groundwater particle flow path to that described above was simulated for the Post-Closure Scenario where the engineered cover and liner were assumed to be compromised. The conservative example illustrated on Figure 4.8 in Golder 2017 is based on a flow path from the southern end of the ECM to Perch Creek, where groundwater velocities ranged from 0.12 to 0.21 m/d (depending on the position along the flow path). Total travel times between the ECM and Perch Creek ranged from approximately 7 to 12 years. For the Post-Closure scenario with a compromised cover and liner, the simulated groundwater pathway flow rates from the ECM location to Perch Creek were approximately 117 m^3/d. Of this, approximately 92 m^3/d originates from the ECM leachate (i.e., the spillover) and 25 m^3/d originates from upgradient sources (see Figure 4.8 in Golder 2017).
- As shown on Figure 4.9 in Golder 2017, minor localized changes to the directions of groundwater flow occur in the vicinity of the NSDF Project Site as a result of captured and/or redirected water, while the overall groundwater flow paths are the same as under current conditions (i.e., the calibrated model).
- As shown on Figure 4.10 in Golder 2017, the simulated water table remains beneath the top of the clay liner for all Scenarios with the exception of the Post-Closure scenario with a compromised cover and liner. With the exception of the latter simulation, the separation between the top of the clay liner and the water table generally ranged from 3 to 9 m.
- The findings from the sensitivity simulations are also discussed in Golder 2017. In general, the overall groundwater flow paths from the ECM to Perch Creek estimated using the sensitivity simulations are similar to the results of the calibrated model (i.e., current conditions at the site).

The final cover is designed to minimize water infiltration, to direct percolating or surface water away from the disposed waste. Therefore, the quantities of leachate generated within the ECM will decline over time and it is expected that leachate generation rates will eventually trend toward zero through time as the length of the post-closure time period increases.

5.3.2.6.2 Groundwater Quality

5.3.2.6.2.1 Methods

As discussed in Section 5.3.2.5.2, during operations and the initial post-closure phase when the WWTP is active, leachate from the ECM will be collected and treated prior to discharge (i.e., no linkage pathway). Therefore, the assessment of groundwater quality is focused on predicting changes in the groundwater contaminant concentrations from the leakage of leachate from the ECM during the post-closure phase, after the WWTP has been decommissioned. The assessment of residual effects on groundwater quality is documented in CNL (2016c) and summarized herein.

Groundwater quality effects were represented for the period after the end of Institutional Control, while the engineered cover, leachate collection, and water treatment systems are no longer maintained. Prior to this period the ECM cover and base liner will be maintained, or the WWTP will be active and no uncontrolled or untreated release to groundwater is expected (CNL 2016c). Conceptually, during the period after then end of institutional control it is expected that rain may infiltrate through the engineered cover into the waste, resulting in leachate generation. As leachate accumulates within the ECM during this period it was assumed that leachate will enter the groundwater flow path through either a breach in the base liner or an overtopping in the south east portion of the ECM (CNL 2016c). With sufficient deterioration of the base liner, leachate will begin to drain from the waste at a rate faster than it can be generated, and the waste will begin to dry.

Chemical and radionuclide concentrations and activities in leachate during the operations phase were calculated by AECOM (2016a) using a partitioning model. The results from this study are summarized in Table 5.3.2-5 and Table 5.3.2-6, respectively. Results shown represent the maximum calculated concentration or activity in the operations period. The concentrations of non-radiological constituents in the leachate are not expected to vary with time during the operations period (AECOM, 2016a), or through the post-closure period prior to the release of leachate (either through a breach in the base liner or an overtopping). For the radionuclides, radioactive decay and ingrowth following the end of the operations phase will likely result in a change in activity.

Values shown in both tables are compared to the Contaminants of Potential Concern (COPC) Screening Limits for surface water, and non-radiological parameters are also compared to Risk Benchmarks for surface water, as reported in CNL (2017). As groundwater is expected to discharge to surface water in the scenarios considered herein, drinking water quality criteria are not shown. The RESidual RADioactivity (RESRAD) computer code version 3.1 was used to evaluate the leaching of radionuclides from the NSDF Project site in the post-closure period, while RESRAD OFFSITE was used to simulate contaminant transport through groundwater flow towards Perch Creek and the activities of radionuclides in the ECM in year 2400 (CNL, 2016c). The estimated activities in the ECM in the year 2400 account for decay and ingrowth, and are presented in Table 5.3.2-6.The transport model was constructed based on the conceptual groundwater flow model described in Section 5.3.2.6.1 and calibrated to the contaminant transport times. Calibrated input parameters to the RESRAD OFFSITE model are summarized in Table 5.3.2-7.

Table 5.3.2-5: Non-Radioactive Constituent Concentrations in Leachate (Operations Period)

Constituent	Contaminant of Potential Concern Screening Limits[1] (mg/L)	Risk Benchmarks[2] (mg/L)	Concentration in Leachate[3] (mg/L)
Cations			
Aluminum	0.05	0.1	**<u>0.15</u>**
Arsenic	0.005	0.066	0.004
Barium	0.004	0.11	**<u>1.8</u>**
Cadmium	0.00009	0.001	**<u>0.003</u>**
Calcium	1160	--	100
Cesium	--	--	0.01
Chromium	0.001[4]	0.016	<u>0.005</u>
Copper	0.002	--[5]	<u>0.1</u>
Iron	0.3	3.4	**<u>125</u>**
Lead	0.001	0.007	**<u>0.02</u>**
Magnesium	82	--	68
Manganese	0.12	2.3	**<u>5.8</u>**
Sodium	680	--	100
Potassium	53	--	26
Silica	--	--	5
Strontium	1.5	15	0.1
Zinc	0.02	0.12	**<u>0.2</u>**
Anions			
Chloride	120	640	17
Fluoride	0.12	3	<u>0.9</u>
Phosphate	--	--	4
Sulfate	128 to 429[6]	--	207
Organics/Other			
Acetone	--	--	1.2
Chrysene	1×10^{-7}	0.001	<u>$2.2x10^{-5}$</u>
Dioxin	1×10^{-8}	0.0001	<u>$2.5x10^{-7}$</u>
EDTA	--	--	1
Fluoranthene	8×10^{-7}	0.0336	<u>$5.3x10^{-5}$</u>
Furan	--	--	$1.1x10^{-9}$
PCBs	0.000001	0.002	<u>$8.9x10^{-5}$</u>
Tannic Acid	--	--	50
Tetrachloroethylene	--	--	0.034
Trichloroethylene	--	--	0.04

1: Contaminant of Potential Concern (COPC) Screening Limits from CNL (2017). Exceedances in leachate are <u>underlined</u>
2: Risk Benchmarks from CNL (2017). Exceedances in leachate are **bold**
3: From AECOM (2016a)
4: Limit for Chromium VI shown
5: If hardness is unknown use Screening Limit
6: Varies as a function of hardness
mg/L = milligrams per litre

Table 5.3.2-6: Radionuclide Activities in Leachate

Nuclide	Contaminant of Potential Concern Screening Limits in water[1] (Bq/L)	Activity in Waste (Operations Period)[2] (Bq/g)	Activity in Waste (Year 2400)[3] (Bq/g)	Activity in Leachate (Operations Period)[2] (Bq/L)
Ac-227	14.7	6.47E-08	6.70E-04	7.6E-09
Ag-108m	—	1.03E-02	9.36E-03	5.5E-03
Am-241	16.2	1.46E+03	1.03E+01	<u>2.4E+01</u>
Am-243	—	3.65E-03	6.98E-03	1.1E-04
C-14	8400	3.06E+02	1.55E+01	1.0E+03
Cl-36	—	3.70E+01	7.07E-02	4.0E+02
Co-60	326	5.85E+04	2.29E-16	<u>2.7E+03</u>
Cs-135	—	4.96E-02	2.43E-03	9.0E-03
Cs-137	291	3.18E+04	3.00E+01	<u>5.0E+03</u>
H-3	—	3.06E+04	1.60E-05	9.1E+06
I-129	—	4.18E+02	5.43E-01	1.5E+03
Mo-93	—	5.58E-06	1.20E-05	3.0E-06
Nb-94	—	5.16E+00	1.08E+01	9.0E-01
Ni-59	—	3.73E+01	2.44E-02	1.8E+01
Ni-63	—	5.25E+02	5.97E-01	2.4E+02
Np-237	49.6	1.25E-03	3.06E-03	2.2E-02
Pa-231	143.6	2.70E-07	7.30E-04	1.0E-08
Pb-210	1117.4	1.62E-09	1.83E-01	2.4E-10
Pu-239	35.2	1.55E+01	7.29E-01	8.2E+00
Pu-240	45.9	9.63E+00	1.11E+00	5.4E+00
Pu-241	—	6.80E-02	4.26E-10	2.8E-03
Pu-242	—	7.05E-04	3.44E-03	4.3E-05
Ra-226	28.6	4.05E+00	1.80E-01	1.4E-01
Se-79	—	2.36E-03	7.89E-04	7.2E-04
Sn-126	—	3.73E-03	1.16E-03	5.6E-04
Sr-90	666	8.30E+02	7.18E-02	<u>4.8E+03</u>
Tc-99	71780	5.63E+00	2.52E+00	1.8E+03
Th-229	2.2	5.82E-05	2.43E-04	2.2E-07
Th-230	15.28	2.55E-06	4.86E-03	9.5E-09
Th-232	17.6	4.72E-01	1.20E-13	1.2E-02
U-233	148	4.30E-02	6.89E-03	9.3E-03
U-234	149.9	2.46E-01	1.42E+00	5.3E-02
U-235	16169	4.36E-03	9.12E-02	9.4E-04
U-236	—	3.21E-04	1.27E-05	7.0E-05
U-238	168.35	6.25E-02	4.55E+00	1.4E-02

1: Contaminant of Potential Concern (COPC) Screening Limits from CNL (2017). Exceedances in leachate are <u>underlined</u>

2: From AECOM (2016a)

3: From CNL (2016c)

Bq/L = Becquerels per litre; Bq/g = Becquerels per gram

Table 5.3.2-7: RESRAD OFFSITE Input Parameters (From CNL 2016c)

RESRAD Parameter	Value
Site Layout (Section of the ECM where the breach/overtopping occurs)	282 meters × 382.5 meters
Hydraulic conductivity of the saturated zone	5,360 metres/year
Effective porosity	0.3
Hydraulic gradient of the saturated zone	0.007 m/m (conservatively adjusted from 0.006)
Depth of aquifer contributing to Perch Creek (m below water table)	3 meters (below the water table)
Infiltration through cover	0.3 meters/year
Longitudinal dispersivity of the saturated zone	0.3 m

m/m = metres per metre.

For leachate released from the ECM through a breach in the base liner it was assumed that contaminants would be transported to Perch Creek via the groundwater flow system, where it would discharge and eventually flow to the Ottawa River. Decay and dispersion in groundwater were represented for this pathway. It was assumed that leachate released from the ECM due to the “Bathtub” overtopping effect would discharge directly into Perch Creek without any reduction in concentrations due to decay or dispersion in groundwater (CNL 2016c).

5.3.2.6.2.2 Application Case Results

The rate of leaching of radionuclides through the base of the failed base liner system is presented in CNL (2016c) for a period of 100,000 years following the end of institutional control. The total radionuclide flux rate from the ECM through this pathway is approximately 4×10^{11} Becquerels per year (Bq/year) at the end of institutional control, and drops to 2×10^{10} Bq/year after 100 years and 1×10^{9} Bq/year after 10,000 years (CNL 2016c). These fluxes are subjected to dispersion and decay in the groundwater flow path. The flux of radionuclides released from the ECM due to the “Bathtub” effect are summarized in Table 5.2.3-8 below. These fluxes are assumed to discharge directly to Perch Creek, and are not subjected to dispersion or decay in the groundwater flow path (CNL 2016c). The rates shown in Table 5.3.2-8 are similar to the initial flux rates through the failed base liner system for the parameters shown in CNL (2016c) (i.e., C-14, Cl-36, Tc-99).

Table 5.3.2-8: Flux of Radionuclides flowing out of the ECM due to the "Bathtub" Effect (from CNL 2016c)

Radionuclide	Flux out of the Contaminated Zone (Bq/year)
Ac-227	1.07E+06
Ag-108m	2.52E+06
Am-241	7.77E+07
Am-243	5.25E+04
C-14	2.48E+10
Cl-36	3.71E+08
Co-60	1.16E-08
Cs-135	2.12E+05
Cs-137	2.62E+09
H-3	2.92E+06

Table 5.3.2-8: Flux of Radionuclides flowing out of the ECM due to the "Bathtub" Effect (from CNL 2016c)

Radionuclide	Flux out of the Contaminated Zone (Bq/year)
I-129	9.67E+08
Mo-93	3.09E+03
Nb-93m	5.60E+07
Nb-94	1.39E+08
Ni-59	5.63E+06
Ni-63	1.38E+08
Np-237	3.93E+06
Pa-231	1.31E+04
Pb-210	5.90E+07
Po-210	5.81E+08
Pu-239	2.14E+07
Pu-240	3.25E+07
Pu-241	1.25E-02
Pu-242	1.01E+05
Ra-226	3.07E+06
Ra-228	1.95E-06
Se-79	1.16E+05
Sn-126	8.32E+04
Sr-90	3.36E+07
Tc-99	3.29E+11
Th-228	2.03E-07
Th-229	4.37E+02
Th-230	8.73E+03
Th-232	2.15E-07
U-233	7.19E+05
U-234	1.48E+08
U-235	9.51E+06
U-236	1.32E+03
U-238	4.75E+08
Zr-93	2.80E+07

Activities in groundwater in the flow path between the ECM and Perch Creek are not presented in CNL (2016c) for either release scenario, as doses were evaluated based on exposure to surface water following groundwater discharge.

Transport modelling to assess the concentrations of non-radiological contaminants in groundwater downstream of the ECM has not yet been developed (AECOM 2016b). Of the non-radiological constituents of leachate shown in Table 5.3.2-5, only aluminum, barium, cadmium, iron, lead, manganese, and zinc were in exceedance of the risk benchmarks for surface water (as documented in CNL 2017). Each of these contaminants have the potential to be attenuated in the groundwater flow path between the ECM and Perch Creek.

5.3.2.7 Prediction Confidence and Uncertainty

Hydrogeological modelling was completed to estimate the groundwater flow pathways from the ECM, and the rates of groundwater flow from the NSDF Project Site to downstream receptors. To achieve this objective, a deterministic approach was used where a 3D numerical (MODFLOW) groundwater model was constructed and calibrated to represent the “best estimate” of groundwater flow conditions based on the conceptual model described above. In order to address the uncertainty associated with the “best estimate” configuration, a sensitivity analysis was completed, which involved perturbation of some of the key model input parameters and comparison to the base case results. A total of four sensitivity simulations were completed, which addressed potential variation in the hydraulic conductivity of the bedrock and sand units, as well as the recharge distribution. All sensitivity simulations resulted in slight changes to the goodness of fit to model calibration data, though in all cases the results were acceptable.

The sensitivity of the RESRAD and RESRAD OFFSITE model to the distribution coefficient applied to the aquifer material and sediment was evaluated by reducing the distribution coefficients for the radionuclides of concern by 50% (CNL 2016c). The estimated doses were similar to those for the application case scenarios (CNL 2016c).

5.3.2.8 Monitoring and Follow-up

A groundwater monitoring network will be developed including installation of groundwater monitoring wells to monitor hydraulic and chemical conditions in preferential flow zones in both vertical and horizontal orientations along the critical flow pathways. The main emphasis of the groundwater monitoring program is to monitor locations that are downgradient from the ECM. The groundwater monitoring program developed for the NSDF Project will be integrated into the overall CNL Groundwater Monitoring Program, and will be compliant with CSA N288.7-15. Groundwater monitoring will continue through operations, closure and post-closure. The number of parameters and locations may changed based annual review of monitoring data. Initial sampling frequency will likely be twice per year (Spring and Fall) consistent with the existing site groundwater monitoring program (Table 5.3.2-9).

Table 5.3.2-9: Monitoring and Follow-up Programs for Hydrogeology

Valued Component	Project Phase and Potential Effect	Monitoring Program Objective	Conceptual Monitoring Program	Suggested Duration	Implementing Program
Hydrogeology	The NSDF may affect groundwater quality during operation, closure and post-closure	▪ Verify EA predictions on groundwater from the ECM and WWTP operation. ▪ Verify the effectiveness of mitigation.	▪ Water elevation measurements to determine groundwater flow direction and gradients ▪ Sampling to confirm groundwater quality to detect potential releases of constituents from the ECM containment area ▪ Initial sampling frequency will likely be twice per year (Spring and Fall).	▪ Groundwater monitoring will continue through operations, closure and post-closure. The number of parameters and locations may changed based annual review of monitoring data.	▪ NSDF Project groundwater monitoring will be integrated into the overall CNL Groundwater Monitoring Program, and will be compliant with CSA N288.7-15.

5.3.2.9 Conclusions

Valued components refer to environmental features that may be affected by a project and that have been identified to be of concern by the proponent, scientists, government agencies, First Nation and Métis peoples, or the public (The Agency 2014). Hydrogeology is recognized as an important component of the environment that may be affected by the NSDF Project and changes to hydrogeology could, in turn, lead to effects on other VCs selected for assessment. Acknowledging that changes to groundwater quantity and quality are considered to be important aspects of the natural and human environment, hydrogeology is referred to as an intermediate component. Results of the analysis of changes in measurement indicators for geology are provided to other disciplines for inclusion in their assessment.

The residual effects on hydrogeology are related to the alteration of groundwater levels and flows due to the construction of the NSDF Project and potential changes to groundwater quantity and quality due to leakage from the ECM following post-closure activities (Table 5.3.2-10). Residual effects to groundwater from leakage of leachate from the ECM during operations are not anticipated due to the implementation of environmental design features, mitigation and operational monitoring plans. Environmental design features and mitigation implemented to reduce residual effects on groundwater quantity and quality include:

- discharge of treated effluent to the exfiltration gallery area will help to reduce water loss from the hydrogeological system;
- a Surface Water Management Plan will be implemented;
- the composite base liner design will include both primary and secondary liner systems;
- the primary liner will include a leachate collection system with the secondary liner housing a leak detection system;
- the HDPE geomembrane was selected as it is compatible with the leachate generated by the waste and will achieve a long service life; and,
- Sampling of the treated effluent discharge will be completed in accordance with CNL’s Management and Monitoring of Emissions Procedure.

A conceptual groundwater model was developed that identified the key hydrostratigraphic units controlling groundwater flow, the hydraulic properties of these units, and the directions and rates of groundwater flow. The general findings from this assessment indicated that groundwater flow primarily occurs through the sandy overburden units (the Upper Sand, Middle Sand, and Basal Sand/Till), whereas the bedrock is considered to be of low transmissivity. Groundwater flow patterns generally follow topography, with recharge occurring in the upland areas and with the ultimate discharge location at Perch Lake or Perch Creek. Groundwater recharge and discharge occurs locally in streams within the lower Perch Lake basin.

Hydrogeological modelling was completed to estimate the groundwater flow pathways from the ECM, and the rates of groundwater flow from the NSDF Project Site to downstream receptors. This was accomplished by constructing a groundwater flow model based on the conceptual model and calibrating it to the existing conditions. In general, minor localized changes to the directions of groundwater flow are predicted to occur in the vicinity of the NSDF Project site as a result of captured and/or redirected water, while the overall groundwater flow paths are the same as under current conditions. However, with final cover placement, quantities of leachate generated

within the ECM will decline and it is expected that leachate generation rates will eventually trend toward zero through time as the length of the post-closure time period increases. The flux of radionuclides from the ECM to groundwater through the post-closure period was calculated. The discharge of this groundwater to surface water in Perch Creek was included in an evaluation of doses to receptors.

A groundwater monitoring network will be developed including installation of groundwater monitoring wells to monitor hydraulic and chemical conditions in preferential flow zones in both vertical and horizontal orientations along the critical flow pathways. The main emphasis of the groundwater monitoring program is to monitor locations that are downgradient from the ECM. The groundwater monitoring program developed for the NSDF Project will be integrated into the overall CNL Groundwater Monitoring Program, and will be compliant with CSA N288.7-15. Groundwater monitoring will continue through operations, closure and post-closure.

Table 5.3.2-10: Summary of Predicted Residual Adverse Effects for Hydrogeology Valued Components

Valued Components	Residual Adverse Effects	Project Effect Occurs in	Contributing Project Activity	Proposed Mitigation
Groundwater quantity	The construction of the NSDF Project will physically alter groundwater levels and flows.	Construction through to post-closure	Construction of the ECM	■ The NSDF Project footprint has been designed to limit disturbance to the natural environment. ■ Discharge of treated effluent to the exfiltration gallery area will help to reduce water loss from the hydrogeological system.
Groundwater quantity and quality	Leakage of leachate from the ECM during the post-closure phase (i.e., after Year 2400) from liner and cover failure as a result of normal evolution can cause changes to groundwater quality.	Post-closure	Liner and cover failure as a result of normal evolution	■ The final cover system will be constructed to promote the shedding of surface water to mitigate infiltration into the mound, and minimize leachate generation. ■ The cover system design incorporates a series of shallow, trapezoidal, riprap-lined drainage channels that are designed to convey water at low velocity. ■ The perimeter road ditch will route the runoff around the ECM perimeter to minimize ponding of water into the closed ECM, erosion of the cover and underlying waste materials, destabilization of the ECM structure, and damage to access roads. ■ The ECM final grading and drainage plan also includes collection ditches along the top of the ECM berm road to collect side slope drainage.

5.0 ENVIRONMENTAL EFFECTS

5.4 Surface Water Environment

This section of the Environmental Impact Statement (EIS) for the Canadian Nuclear Laboratories (CNL) Near Surface Disposal Facility (NSDF) Project seeks to understand and characterize potential residual effects of the NSDF Project and other past, present, and reasonably foreseeable developments on the physical aspects of the environment. Section 5.4.1 focuses on hydrology and Section 5.4.2 focuses on surface water quality.

5.4.1 Hydrology

5.4.1.1 Scope of the Assessment

This section focuses on hydrology, which includes surface water quantity, flow and direction. The hydrology assessment follows the overall environmental assessment approach and methods described in Section 5.1. The assessment is completed in the following key steps:

- **Step 1 – Identify Valued Components (VCs) and define the spatial boundaries, temporal boundaries, and assessment cases** for the hydrology assessment (refer to Sections 5.4.1.2 Valued Components and Section 5.4.1.3 Assessment Boundaries). The VCs and measurement indicators used to assess NSDF Project-related changes to hydrology, the spatial and temporal boundaries at which the assessment occurred and the assessment cases considered are described.
- **Step 2 – Describe the existing conditions** (refer to Section 5.4.1.4 Description of the Environment). Existing conditions in the local and regional areas are described, including the combined effects of previous and existing developments (Base Case). The existing environment represents the historical and current environmental pressures that have shaped the observed patterns in the environment (i.e., natural variation).
- **Step 3 – Evaluate Project interactions and mitigation** (refer to Section 5.4.1.5 Project Interactions and Mitigation). The NSDF Project components and/or activities with the potential to affect hydrology are identified and mitigation developed to limit or avoid effects is presented. A pathways analysis is then used to focus further assessment on key interactions between the NSDF Project and the environment by evaluating the different effect pathways to determine if, after incorporation of mitigation, there is still potential to cause residual effects. Where effects are adequately mitigated and are not forwarded for further analysis (i.e., secondary pathways, or where mitigation will remove the pathway altogether), the reasons for concluding the assessment at this stage are articulated. Primary pathways that may lead to residual effects to hydrology after incorporating mitigation are carried forward to Step 4 for further analysis and residual effects characterization.
- **Step 4 – Present the methods and results of the residual effects analysis** (refer to Section 5.4.1.6 Residual Effects Analysis). This section outlines the methods used to predict and characterize residual effects to hydrology from primary effect pathways. The analysis results are also presented including the characterization of incremental effects from the NSDF Project, as well as cumulative effects of the NSDF Project in combination with other reasonably foreseeable developments (if applicable). A key outcome of this section is the predicted changes to surface water quantity that are passed on to other disciplines for their assessment.

- **Step 5 – Describe the level of certainty and management of uncertainty** (refer to Section 5.4.1.7 Prediction Confidence and Uncertainty). Evaluate the available literature, data, and models used for the assessment, and describe the level of certainty that can be placed on predicted residual effects. This section will also identify how the uncertainty has been managed so that the effects are not underestimated.
- **Step 6 – Identify monitoring and follow-up** required to confirm effects predictions and address uncertainty (refer to Section 5.4.1.8 Monitoring and Follow-up).
- **Step 7 – Present a consolidated summary of conclusions** and outcomes of the assessment of residual effects on hydrology (refer to Section 5.4.1.9 Conclusions).

This section also describes how the input from engagement influenced the scope of the hydrology assessment. To date no areas of interest have been raised by the public, communities of interest, regulators, and First Nations and Métis communities during engagement activities specific to hydrology.

5.4.1.2 Valued Components

Valued components refer to environmental features that may be affected by a project and that have been identified to be of concern by the proponent, scientists, government agencies, Aboriginal peoples, or the public (The Canadian Environmental Assessment Agency [The Agency] 2014). Hydrology, which includes surface water quantity, flow and direction, is recognized as an important component of the environment that may be affected by the NSDF Project and changes to hydrology could, in turn, lead to effects on other VCs selected for assessment. For example, changes to the characteristics of hydrology, such as water quantity, have a large influence on the local and regional diversity, contributing to the spatial and temporal distribution of aquatic and terrestrial ecosystems. Subsequently, changes to these characteristics by NSDF Project activities could affect fish and wildlife, and land and resource use (Table 5.4.1-1).

Acknowledging that changes to hydrology are considered to be important aspects of the natural and human environment, hydrology is referred to as an intermediate component (i.e., it does not have an assessment endpoint). Changes to intermediate component VCs must be understood to facilitate assessment of project interactions. The hydrology assessment, therefore, is analyzed for incremental and cumulative (if applicable) changes in the relevant measurement indicators associated with hydrology (Table 5.4.1-2). The changes are characterized in terms of magnitude, duration and geographic extent, but are not classified using rankings for effects criteria. The hydrology assessment also does not include the assessment of the significance of these changes; rather, results of the analysis of changes in measurement indicators for hydrology are provided to other disciplines for inclusion in their assessment (Table 5.4.1-2).

Table 5.4.1-1: Valued Components for Hydrology Assessment

Valued Component	Rationale for Selection
Hydrology	■ The NSDF Project may affect existing availability of the spatial and temporal distribution of water quantity for aquatic and terrestrial biodiversity, which can subsequently affect land and resource use. ■ Societal values concerning changes in water quantity are an important consideration in understanding potential effects of the NSDF Project.

Table 5.4.1-2: Measurement Indicators for the Hydrology Assessment

Valued Component	Measurement Indicators	Discipline Assessments where Effects on Hydrology are Considered
Hydrology	■ Peak flow rates, time to peak flow and total run-off volumes ■ Stream channel parameters (e.g., channel depths, widths) and shoreline integrity	■ Section 5.4.2 Surface Water Quality ■ Section 5.5 Aquatic Biodiversity ■ Section 5.6 Terrestrial Biodiversity ■ Section 5.9 Land and Resource Use

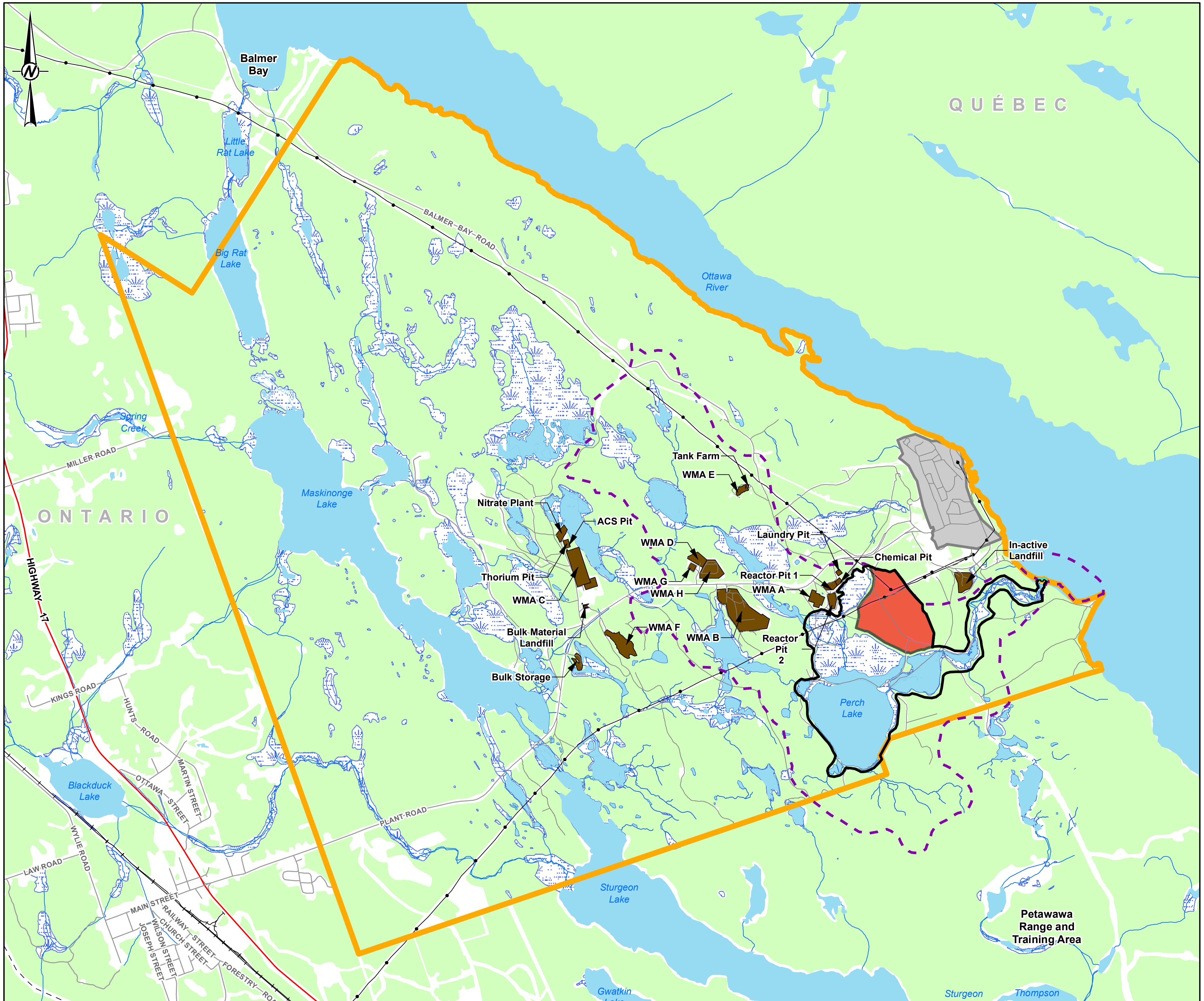
5.4.1.3 Assessment Boundaries

5.4.1.3.1 Spatial Boundaries

The spatial boundaries selected for the hydrology assessment were chosen because they permit description of existing conditions in sufficient detail to enable potential project-VC interactions and effects to be identified, understood, and assessed, including understanding and assessing the contribution of the NSDF Project to cumulative effects. The spatial boundaries selected for the hydrology are consistent with the surface water quality and aquatic biodiversity assessment are presented on Figure 5.4.1-1 and are described below:

- **Site Study Area (SSA):** the SSA is the NSDF Project footprint (i.e., where project activities would be undertaken including the NSDF Project's proposed facilities, buildings and infrastructure).
- **Local Study Area (LSA):** the LSA is defined as the area within which there is potential for measurable changes to measurement indicators resulting from the proposed NSDF Project activities. The LSA includes the SSA and is bounded by Perch Lake and Perch Creek, and adjacent wetlands and swamps.
- **Regional Study Area (RSA):** the RSA is defined as the area within which the potential effects of the NSDF Project may interact with the effects of other existing or reasonably foreseeable projects. The RSA for hydrology is determined by the spatial extent of the Perch Lake watershed, and includes Perch Lake and its tributaries, and Perch Creek. Although the Ottawa River in the vicinity of the mouth of Perch Creek is included in the RSA, the river beyond this location lies outside the boundary of the assessment.

This page left intentionally blank



LEGEND

- HIGHWAY
- ROAD
- RAILWAY
- HYDRO LINE
- NATURAL GAS PIPELINE
- RIVER/STREAM
- WATERBODY
- WETLAND
- WOODED AREA
- SITE STUDY AREA (NDSF PROJECT SITE)
- CRL MAIN CAMPUS
- CRL PROPERTY
- WASTE MANAGEMENT AREA (WMA)[1]
- LOCAL STUDY AREA
- REGIONAL STUDY AREA

1 0 1
1:35,000 KILOMETERS

NOTE(S)
1. LIQUID DISPOSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.

REFERENCE(S)
1. BASEDATA ONTARIO MNRF 2016, CANVEC 2016, AND CNL 2016
2. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
3. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18N

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
SPATIAL BOUNDARIES SELECTED FOR THE HYDROLOGY AND SURFACE WATER QUALITY ASSESSMENT

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	MM
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.4.1-1

S:\Clients\Canadian_Nuclear_Laboratories\NSDF\99_PROJ\1547525_NSDF_EIS\40_PROD\0009_EIS_Section_5\Section_5.4_Surface_Water\1547525-0009-CH-0001.mxd

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:
25mm

This page left intentionally blank

5.4.1.3.2 Temporal Boundaries

Temporal boundaries (i.e., project phases) establish the timeframe during which NSDF Project effects are assessed. The temporal boundary represents the timeframe during which project activities are actively occurring, and considers the duration of predicted residual effects. The duration of an effect is defined as the amount of time between the start and end of a Project activity or stressor (which is related to the project phases) plus the time required for the residual effect to be reversed. In some cases, a residual effect may be irreversible within the temporal boundaries of the Project or if the effects were predicted to last so far into the future that they could not be predicted with any level of certainty (e.g., residual effect lasts for thousands of years). The following phases were identified for the NSDF Project:

- **Construction Phase**: includes site preparation and all activities associated with the construction of the NSDF. This phase includes activities such as installing the necessary supporting and/or ancillary facilities and NSDF infrastructure to facilitate NSDF operations, inactive commissioning and systems testing, and transportation of construction materials. Construction activities are expected take place from 2018 to 2020.

- **Operations Phase**: includes all activities associated with the landfilling of waste receipt, waste placement, water management, wastewater treatment plant operations, vehicle movements into and from the NSDF Project site, and maintenance activities. Operations activities are expected to last approximately 50 years (i.e., 2020 to 2070).

- **Closure Phase:** includes activities necessary to complete the installation of the final cover and implementation of long-term monitoring. Closure activities are expected to start in 2070 and continue through to 2100, after which the NSDF Project will transfer into the post-closure phase.

- **Post-closure Phase:** has two discrete periods: Institutional Control and post-Institutional Control. The Institutional Control period includes implementation of both active and passive control throughout 2100 to 2400 (i.e., 300 years). During Institutional Control, groundwater monitoring and groundwater quality management will continue to demonstrate compliance with the safety case assumptions. Post-institutional Control occurs after year 2400 and continues indefinitely.

The temporal boundaries for the hydrology assessment include consideration of effects of the NSDF Project during the operations and post-closure phases.

5.4.1.3.3 Assessment Cases

The assessment cases considered in the hydrology assessment include the Base Case and Application Case:

- **Base Case –** This scenario represents existing conditions and characterizes combined effects from previous and existing developments and activities. The Base Case reflects the effects of existing disturbances, such as forestry, transportation, agricultural, mining, and residential and recreational development. Current effects from the existing Chalk River Laboratories (CRL) facilities and operations, for example, are considered part of the Base Case.

- **Application Case –** This scenario represents predictions of the effects of the Base Case combined with the effects that may result from the NSDF Project. The Application Case considers potential effects from the NSDF Project during construction through to the closure and post-closure phase.

- **Reasonably Foreseeable Development (RFD) Case –** This scenario represents predictions of the cumulative effects of the Application Case, which includes the Base Case, plus projects that are currently under application review or that have officially entered a regulatory application process, and are therefore, considered reasonably foreseeable. There are no RFDs expected in the CRL property (i.e., the RSA) with the exception of new/upgrades to research and development facilities, new support infrastructure, and ongoing decommissioning and environmental restoration activities. New support infrastructure and research and development facilities will be located within existing disturbed areas on the CRL property (i.e., no disturbance to Greenfield areas). Potential effects from these activities are not expected to have an interaction with hydrology. The end-state plan for the CRL site will be to return lands disturbed by site activities to a condition that is physically stable, and safe in keeping with the land use and landscape of the day. Therefore, decommissioning and environmental restoration activities are anticipated to positively affect hydrology. Because RFDs will either have no spatial overlap or are likely to positively affect the hydrology, an RFD Case is not presented as part of this assessment.

5.4.1.4 Description of the Environment

5.4.1.4.1 Methods

Existing hydrological conditions (e.g., flow, direction, quantity, velocity) within and surrounding the CRL property, including the Ottawa River, were obtained from published hydrology reports and available baseline data. Regional and local hydrology described in the 2010 Environmental Impact Statement for Atomic Energy of Canada Limited's (AECL) National Research Universal Reactor Long-Term Management Project (AECL 2010) is summarized in the following sections. The hydrological baseline conditions for Perch Lake and Perch Creek are also presented. Rainfall data was sourced from the Ontario Ministry of Transportation (MTO).

5.4.1.4.2 Results

5.4.1.4.2.1 Drainage Conditions

The drainage basin slopes from a highpoint ridge (elevation 195 metres above sea level [masl]) along the eastern limit of the Site, westerly towards Perch Lake and the wetlands located on the Site's western boundary (elevation 160 masl). Golder site investigations conducted in 2014 describe the surface soils as primarily fine sands underlain by sandy tills (Golder 2016). Currently much of the area is heavily treed and undisturbed indicating good infiltration capacity. Topsoil thickness ranged from 50 to 230 millimetres (mm), while overburden depth to bedrock was 0.5 to 11.4 metres below ground surface (mbgs). Groundwater table depth varied significantly throughout the site ranging from 0.2 metres (m) in the vicinity of the wetlands to 11.4 m deep in the northern section of the NSDF Project site which corresponds to the thickest overburden. A delineation of the drainage basin is presented in Figure 5.4.1-2. Surface water flow is generally dispersed as shallow sheet flow, with the only channel flow occurring within the wetlands at the southern and western boundaries of the basin.

5.4.1.4.2.2 Ottawa River

The CRL property, as well as the surrounding area, is located entirely within the Ottawa River watershed, which has several sub-watersheds (i.e., drainage basins). The Chalk River and Petawawa Rivers are the two major tributaries near the CRL property. Approximately 12% of the CRL property flows directly into the Ottawa River (Figure 5.4.1-2), and includes the CRL Built-Up Area Basin of the CRL property, where most of the operational nuclear and industrial facilities are located (CNL 2016a).

In the vicinity of CRL, the Ottawa River has been regulated for purposes of hydroelectric power generation since 1950, and the Ottawa River flow rates are measured at the des Joachims Generating Station approximately 30 kilometres (km) upstream. The measured flow in the Ottawa River is summarized in the following points:

- the highest flow rate on record is 400 million cubic metres per day (m^3/d) or 4,630 cubic metres per second (m^3/s), occurring on May 8, 1970;
- the lowest flow rate on record is 7.9 million m^3/d (91 m^3/s), occurring on October 9, 1955; and
- average flows in the river range between 50 and 100 million m^3/d (600 to 1,200 m^3/s).

The water level in the Ottawa River along the CRL property boundary is controlled by a set of rapids at Cotnam Island located approximately 40 km downstream of the CRL property boundary on the Ottawa River, and by adjustments to the discharge rate at the Des Joachims hydroelectric dam approximately 30 km upstream of the CRL property boundary on the Ottawa River. The Ottawa River water levels at the CRL property boundary are measured daily and have been recorded since 1945. The highest recorded river level at the CRL property boundary (as of June 2002) is 113.6 metres above sea level (masl), which was recorded in April 1979. The lowest level is 110.6 masl recorded in August 1971 (as of June 2002).

5.4.1.4.2.3 Perch Lake Watershed

The NSDF Project is located entirely within the Perch Lake watershed (Figure 5.4.1-2), at the southern edge of the Canadian Shield in the Ottawa River valley (Robertson and Barry 1985). Ground surface elevations range from a low of approximately 160 masl within the low-lying and relatively flat terrain bordering the north side of Perch Lake, to a high of 196 masl along the crest of the ridge to the east of East Mattawa Road that separates the Perch Lake and Ottawa River drainage basins (Golder 2016). The watershed includes Waste Management Area (WMA) A and WMA B, the Reactor and Laundry Pits, and the Liquid Dispersal Area (LDA). From Perch Lake, surface water (Perch Creek) flows in a north-easterly direction through Perch Creek to its confluence with the Ottawa River. The Perch Creek basin drains approximately 18% of CRL property area and drains to the Ottawa River through Perch Lake and Perch Creek (CNL 2016b).

Robertson and Barry (1985) defined the Perch Lake watershed by seven sub-basins, six of which drain into Perch Lake (Figure 5.4.1-2). Basins 1 to 5 drain into the lake through surface streams with discernible channels (Sub-basins 1 to 5) while the sixth basin (Sub-basin B) lacks a discernible stream channel for drainage into Perch Lake. The seventh basin (Border) drains through Perch Creek below the lake outlet and into the Ottawa River. Sub-basin elevation and areas are provided in Table 5.4.1-3.

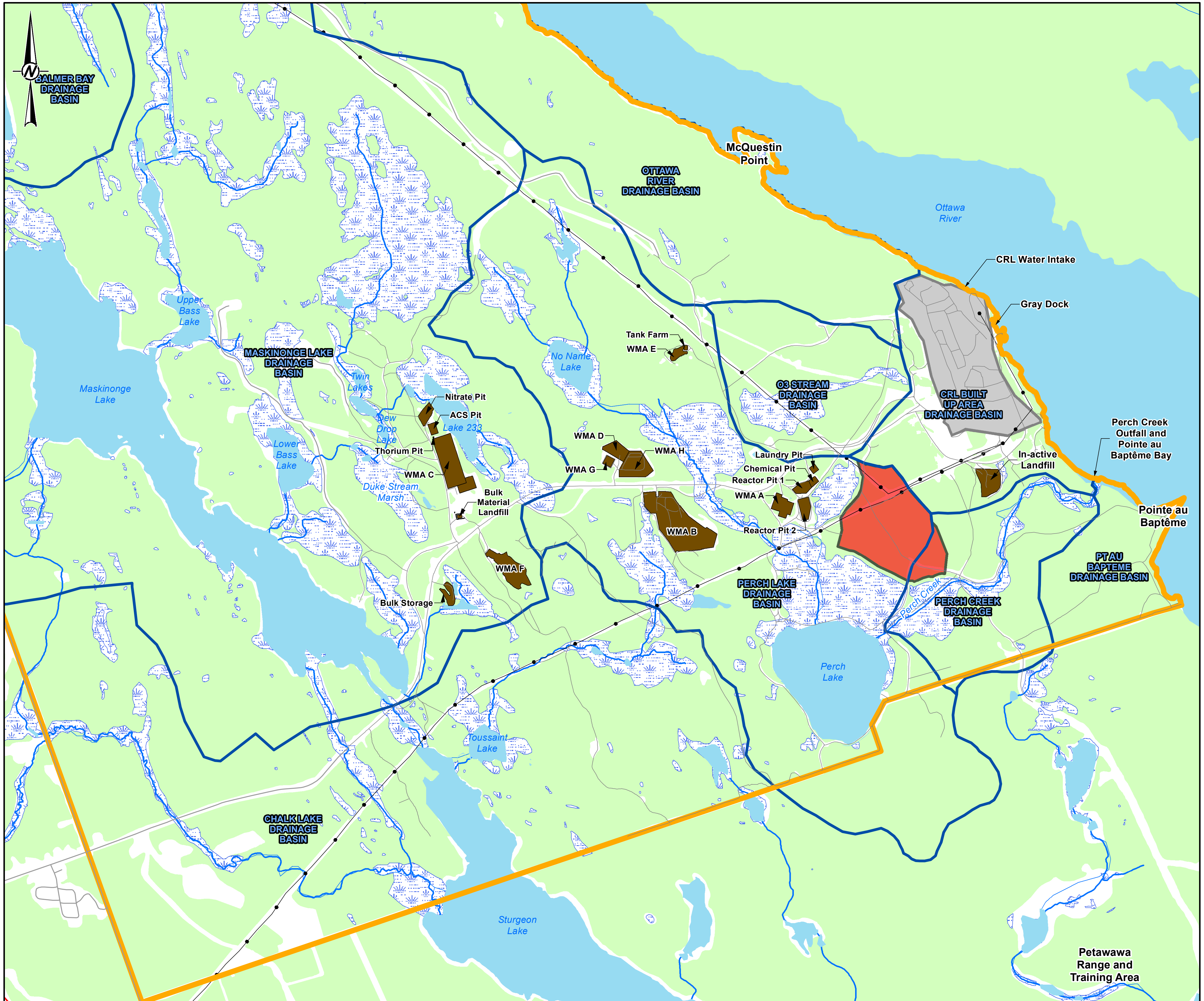
Table 5.4.1-3: Perch Creek Sub-Basin Weir Elevations and Areas

	Elevation[(a)] (masl)	Area (km^2)	Area (ha)
Sub-basin 1	156.27	0.93	93
Sub-basin 2	156.37	3.6	360
Sub-basin 3	156.43	0.81	81
Sub-basin 4	156.28	0.24	24
Sub-basin 5	157.52	0.11	11
Sub-basin B	—	0.093	9.3
Border	—	0.056	5.6
Perch Lake	155.95	0.45	45
Perch Creek	—	1.02	102
	Totals		
	To lake	5.84	584
	To lake outlet	6.29	629
	To basin outlet	7.3	730

Source: Robertson and Barry 1985.

a) measured at weirs, installed in 1969.

masl = metres above sea level; km^2 = square kilometres; ha = hectares; — = unavailable data.



LEGEND

- ROADS
- RAILWAY
- TRANSMISSION LINE
- RIVER/STREAM
- WATERBODY
- WETLAND
- WOODED AREA
- DRAINAGE BASIN
- NSDF PROJECT SITE
- CRL MAIN CAMPUS
- CRL PROPERTY
- WASTE MANAGEMENT AREA (WMA) [1]

NOTE(S)
1. LIQUID DISPOSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.

REFERENCE(S)
1. BASEDATA ONTARIO MNRF 2016, CANVEC 2016, AND CNL 2016
2. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
3. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18N

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
DRAINAGE BASINS WITHIN THE CHALK RIVER LABORATORIES PROPERTY

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	MM
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.4.1-2

This page left intentionally blank

Physical characteristics of Perch Lake include a wetted area of approximately 45 hectares (ha), a drainage area of 730 ha, a maximum depth of 3.5 m, and a mean depth of 2 m, (Robertson and Barry 1985). In late summer and fall, the water level usually drops by as much as 0.25 m. Most of Perch Lake is open water except for littoral zones along the shore, including a region of floating, emergent, and submerged vegetation, which amounts to about 30% of the lake's surface (Yankovich et al. 2000). The outer fringe of this zone is known as Perch Lake Marsh. This open marsh may be considered to be part of the lake, with which it is physically continuous. To the north, there are extensive wetlands, notably Perch Lake Swamp, South Swamp, East Swamp, and West Swamp. The lake is confined in part by sand outcrops along the northern and southern shores, and by bedrock along the western shores.

The hydrology of Perch Lake was studied extensively from 1969 to 1988 (e.g., see Robertson and Barry 1985; Yankovich et al. 2000) through the collection of measurements in a system of dikes and ditches that enabled all surface flows in and out of the lake to be accurately measured. Five of the tributaries to Perch Lake and the outlet stream (Perch Creek) include V-notch weirs. The lake outlet and two of the inlet streams (inlet 2 and 5) are each equipped with a modified V-notch weir. Streams for inlets 1, 3 and 4 are each equipped with 90° V-notch weirs. Most of the weir installations were completed in 1969. The weir at inlet 5 was installed in 1972.

Mean annual flow at the outlet of Perch Lake is 0.057 m^3/s, based on the 11-year average water budget (1969 to 1980) for the hydrologic year (September 1 to August 31; Table 5.4.1-4). Flow results from measurements taken at the weir locations are summarized in Table 5.4.1-4.

Table 5.4.1-4: Perch Lake Hydrology for Inlet Streams (Sub-Basin 1-5) and the Outlet Stream Based on Annual Average Water Budget (1969-1980)

	Mean Annual Flow (m^3/y)	Mean Annual Flow (m^3/s)	Depth Equivalent (m)	Standard Deviation	Coefficient of Variation
Inlet 1	2.15×10^5	0.007	0.23	0.57	0.27
Inlet 2	9.66×10^5	0.031	0.27	3.22	0.33
Inlet 3	1.47×10^5	0.005	0.18	0.68	0.46
Inlet 4	8.30×0^4	0.003	0.35	0.23	0.28
Inlet 5	3.10×10^4	0.001	0.28	0.11	0.36
Total inflow	1.44×10^6	0.046	0.25	4.94	0.34
Precipitation	3.48×10^5	0.011	0.773	0.46	0.13
Total input	1.79×10^6	0.057	0.285	5.05	0.28
Outflow	1.79×10^6	0.057	0.284	5.2	0.29
Evaporation	3.09×10^5	0.010	0.687	0.25	0.08
Groundwater	3.05×10^5	0.010	0.052	0.7	0.23

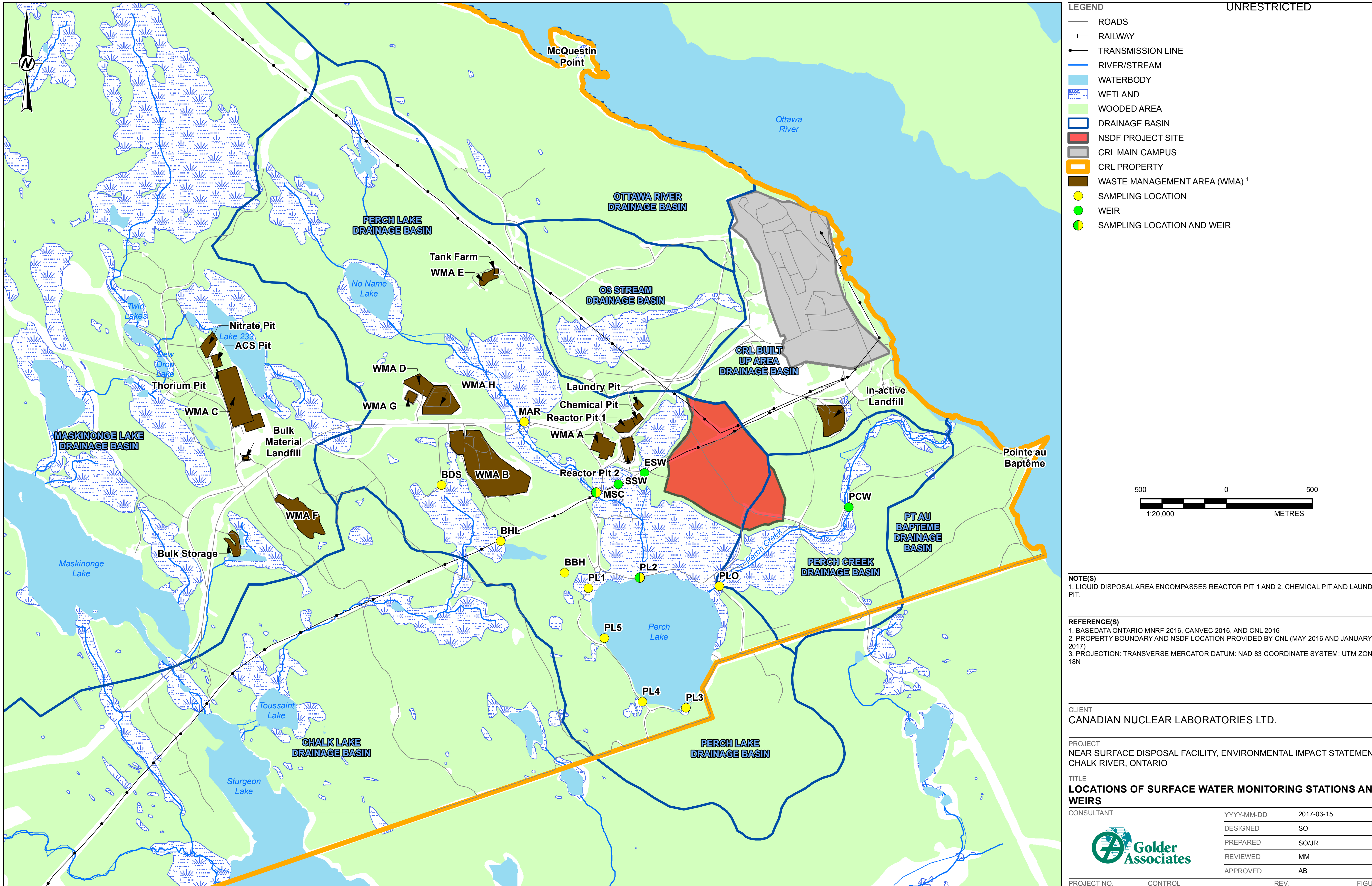
m^3/y = cubic metres per year; m^3/s = cubic metres per second; m = metres.
Source: Robertson and Barry 1985.

In 1988, the wooden weir box at the Perch Lake outlet began to fail, and flow measurements at Perch Lake outlet were discontinued (CNL 2016b). Over the measurement period, the annual average flow out of Perch Lake was 1.70×10^6 cubic metres (m^3). In the mid-1980s a concrete dam fitted with a compound V-notch weir was constructed on Perch Creek approximately 950 downstream of Perch Lake Outlet, and routine streamflow measurements have been collected at the Perch Creek weir since 1992. Between 1992 and 2015 the annual average flow through the Perch Creek weir has been 2.04×10^6 m^3 (CNL 2016b). The annual average total outflow from Perch Creek to the Ottawa River (i.e. Perch lake outflow and water added along Perch Creek) is 2.21×10^6 m^3.

Perch Creek is the dominant surface water feature that drains the Perch Creek Basin directly into the Ottawa River. Perch Creek ranges from about 5 to 10 m in width and generally has a depth of less than 1 m. Figure 5.4.1-3 shows the location of the creek marked by the Perch Creek weir (PCW) northeast of Perch Lake at the extent of the wetlands, approximately 700 m downstream of Perch Lake (Photo 5.4.1-1).

Photo 5.4.1-1. Upstream View of the Perch Creek Weir, August 2012.

Below the Perch Creek weir, the creek enters a mixed deciduous woodlot and overhead cover increases substantially (Sowden and Power 1981). Stream gradient also increases sharply, exceeding a 10% slope in sections. A series of small waterfalls (or cascades) occur just downstream of the weir which then lead to a pool-riffle sequence, followed by slow-flowing water in the lower reach of the creek. The substrate in the middle reach is rock, gravel, and coarse sand; the substrate in the lower section of the creek is dominated by silt and sand substrate. The overall slope of Perch Creek is approximately 3%.



NOTE(S)
1. LIQUID DISPOSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.

REFERENCE(S)
1. BASEDATA ONTARIO MNRF 2016, CANVEC 2016, AND CNL 2016
2. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
3. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18N

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
LOCATIONS OF SURFACE WATER MONITORING STATIONS AND WEIRS

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	MM
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.4.1-3

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm

S:\Clients\Canadian_Nuclear_Laboratories\NSDF\99_PROJ\1547525_NSDF_EIS\40_PROD\0009_EIS_Section_5\Section_5.4_Surface_Water\1547525-0009-CS-0003.mxd

This page left intentionally blank

Flow rates from the Perch Creek weir were measured by CNL from 2009 to 2015 (CNL 2016b), as summarized in Table 5.4.1-5 and in Figure 5.4.1-4. The highest flows typically occur in conjunction with spring melt (i.e., freshet) events in April, while lower flows are encountered during the summer season, particularly in August. The overall annual average flow from years 2009 to 2015 was estimated to be approximately 0.063 m^3/s.

Table 5.4.1-5: Perch Creek Monthly Mean Flows (m^3/s), 2009 to 2015

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
2009	0.030	0.012	0.029	0.191	0.104	0.059	0.041	0.031	0.039	0.049	0.072	0.060	0.060
2010	0.041	0.027	0.048	0.191	0.104	0.059	0.041	0.031	0.039	0.049	0.072	0.060	0.064
2011	—	0.027	0.048	0.191	0.104	0.059	0.041	0.031	0.039	0.049	0.072	0.060	0.066
2012	0.059	0.027	0.222	0.060	0.043	0.020	0.004	0.003	0.008	0.007	0.007	0.007	0.039
2013	0.042	0.027	0.037	0.228	0.163	0.062	0.019	0.012	0.079	0.096	0.050	0.055	0.073
2014	0.042	0.027	0.056	0.377	0.070	0.032	0.099	0.011	0.012	0.026	0.084	0.050	0.074
2015	0.042	0.025	0.074	0.245	0.105	0.028	0.020	0.004	0.034	0.035	0.113	0.049	0.065
Max	0.059	0.027	0.222	0.377	0.163	0.062	0.099	0.031	0.079	0.096	0.113	0.060	0.074
Min	0.030	0.012	0.029	0.060	0.043	0.020	0.004	0.003	0.008	0.007	0.007	0.007	0.039
Mean	**0.045**	**0.027**	**0.081**	**0.215**	**0.098**	**0.043**	**0.037**	**0.015**	**0.035**	**0.044**	**0.066**	**0.047**	**0.063**

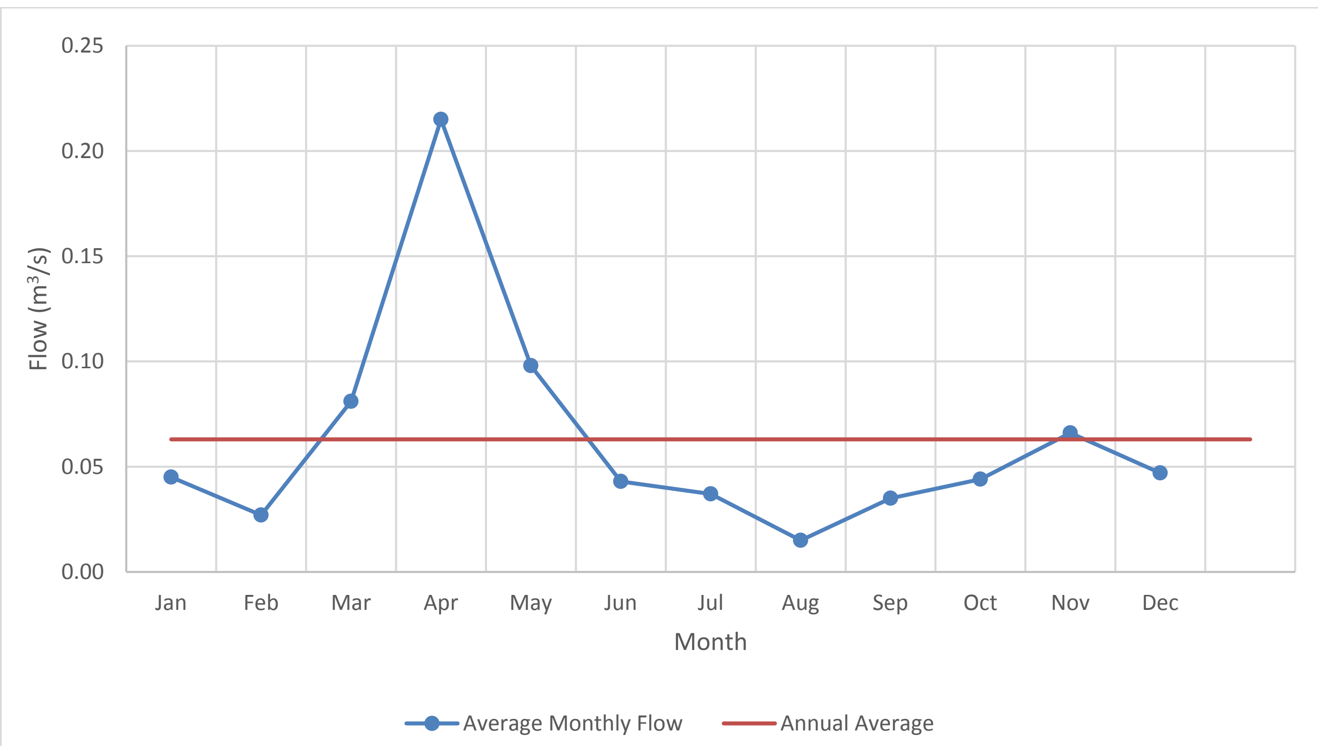


Figure 5.4.1-4: Perch Creek Monthly Mean Flows, 2009 to 2015

5.4.1.4.2.4 Site Study Area

Development of the NSDF Project site involves the construction of three surface water management ponds: surface water management pond #1 is proposed for the northern section of the site with discharge to the East Swamp; and surface water management pond #2 and surface water management pond #3 are proposed for the southern and western sections of the site respectively, both ponds are to discharge to Perch Lake. The current surface water management pond footprints reflect the overall storage required to control post-closure flows to predevelopment levels for the 2-year through to 100-year rainfall events at the site. This volume also contains the storage required for sediment control during construction and water quality control during operations. The current footprints typically assume a maximum 100-year operating water level at a 3 m depth with 1 m of freeboard that includes allowance for climate change impacts and rain on snowmelt.

The surface water runoff within the SSA under existing (Base Case) conditions was modelled using Visual Otthymo 4.0 software for the 2-year through to 100-year rainfall events and the regional storm event for the area (i.e., The Timmins Storm) was also modelled along with the probable maximum precipitation (PMP). Visual Otthymo is a hydrologic management model that is capable of simulating run-off from single storm events. It is well suited to hydrologic studies of watersheds and sub-watersheds and is a useful tool in creating master drainage plans, site stormwater designs and surface water management design. Rainfall intensity data inputted into the model was sourced from the Town of Arnprior as the storm data was more recent than that available from Environment Canada for the area.

Flow modelling was completed to compare run-off from the contributing areas from the pre-development condition to the equivalent areas post-development. Pre-development model outputs for the 1:2 year, 1:5 year, 1:100 year and the Timmins Storm are summarized in Tables 5.4.1-6 to 5.4.1-8.

Table 5.4.1-6: Hydrologic Model Results for Base Conditions Surface Water Management Pond #1

Model Output	Storm Event			
	1:2 Year	1:5 Year	1:100 Year (24 hr duration)	Timmins Storm (12 hour 193 mm)
Peak Runoff Flow Rate	0.03 m^3/s	0.07 m^3/s	0.21 m^3/s	0.23 m^3/s
Time to Peak	6.58 hours	6.6 hours	12.25 hours	7.08 hours
Total Area Run-off	205 m^3	411 m^3	1,439 m^3	3,632 m^3

m^3/s = cubic meters per second; m^3 = cubic metres; mm = millimetres

Table 5.4.1-7: Hydrologic Model Results for Base Conditions Surface Water Management Pond #2

Model Output	Storm Event			
	1:2 Year	1:5 Year	1:100 Year (24 hr duration)	Timmins Storm (12 hour 193 mm)
Peak Runoff Flow Rate	0.11 m^3/s	0.22 m^3/s	0.66 m^3/s	0.65 m^3/s
Time to Peak	6.4 hours	6.4 hours	12.2 hours	7.1 hours
Total Area Run-off	562 m^3	1,127 m^3	3,948 m^3	9,961 m^3

m^3/s = cubic meters per second; m^3 = cubic metres; mm = millimetres

Table 5.4.1-8: Hydrologic Model Results for Base Conditions Surface Water Management Pond #3

Model Output	Storm Event			
	1:2 Year	**1:5 Year**	**1:100 Year (24 hr duration)**	**Timmins Storm (12 hour 193 mm)**
Peak Runoff Flow Rate	0.02 m^3/s	0.05 m^3/s	0.15 m^3/s	0.18 m^3/s
Time to Peak	6.7 hours	6.7 hours	12.42 hours	7.2 hours
Total Area Run-off	173 m^3	346 m^3	1,213 m^3	3,062 m^3

m^3/s = cubic meters per second; m^3 = cubic metres; mm = millimetres

5.4.1.5 Project Interactions and Mitigation

5.4.1.5.1 Methods

This section describes the process by which interactions between NSDF Project components and activities hydrology were identified and evaluated. Potential effect pathways are identified and mitigation developed to eliminate and/or reduce effects is presented. A pathways analysis is then used to focus the assessment on key interactions between the NSDF Project and the environment by evaluating the different effect pathways to determine if, after incorporation of mitigation, there is still potential to cause residual effects. Where effects will be adequately mitigated and are not forwarded for further analysis (i.e., secondary pathways, or where mitigation will remove the pathway altogether), the reasons for concluding the assessment at this stage are articulated. Primary pathways that may lead to residual effects after incorporation of mitigation measures are further characterized in subsequent subsections of the assessment. As such, this section helps to focus the remainder of the assessment on those interactions (effects pathways) likely to result in residual adverse effects.

The first part of the analysis was to identify the potential effects pathways for all phases of the NSDF Project. The next step in the analysis was the development of environmental design features and mitigation that could be incorporated into the NSDF Project to eliminate and/or reduce adverse effects to hydrology. Environmental design features included project design elements, environmental best practices, and management policies and procedures. Environmental design features and mitigation were developed through an iterative process between the NSDF Project's engineering and environmental teams, combined with input from NSDF Project-specific or regional engagement with other interested parties. The design features and/or mitigation were selected considering their effectiveness for implementation and maintenance, and their appropriateness within the context of the identified effect pathways.

After incorporation of mitigation, potential pathways were evaluated into the following categories using scientific knowledge, logic, experience with similar developments, and the effectiveness of environmental design features and mitigation:

- **No linkage pathway –** pathway is removed by environmental design features or mitigation such that the NSDF Project would not be expected to result in a measurable environmental change relative to Base Case values and therefore would have no residual effects to hydrology.
- **Secondary pathway –** the pathway could result in a measurable minor environmental change, but would have a negligible residual effect on hydrology relative to Base Case and/or guideline values and is not expected to contribute cumulatively to other NSDF Project effects or to the effects of other past, present or reasonably foreseeable developments to cause a significant effect.
- **Primary pathway –** the pathway is likely to result in an environmental change relative to the Base Case and/or guideline values that could contribute to residual effects to hydrology.

Environmental design features and mitigation that have been or could be incorporated into the NSDF Project to eliminate and/or reduce adverse effects were considered. Potential pathways that were completely removed due to implementation of environmental design or mitigation were not assessed further. Pathways that were assessed to be secondary and demonstrated to have a negligible residual effect to hydrology through simple qualitative or semi-quantitative evaluation of the pathway were also not advanced for further assessment. Primary pathways were carried forward for more detailed quantitative and qualitative effects analysis to characterize the residual effects of the NSDF Project.

5.4.1.6 Results

Pathways through which all phases of the NSDF Project may interact with and result in changes to measurement indicators for hydrology are provided in Table 5.4.1-9.

Table 5.4.1-9: Pathways Analysis for the Hydrology Valued Component

Project Activity	Effects Pathways	Management Practices and Mitigation Actions	Pathway Assessment
Project activities during the construction phase: ■ Site Preparation ■ Construction of the ECM ■ Blasting (as required) ■ Development of surface water management structures ■ Construction of the WWTP and other support facilities ■ On-site road and access development	The construction of the NSDF Project will physically alter drainage patterns in the Perch Lake watershed, and may change downstream discharge, water levels, and channel/bank stability, and water levels in adjacent wetlands.	■ The NSDF Project footprint has been designed to avoid wetlands and limit disturbance to the natural environment to the extent feasible. For example, as the ECM is developed sequentially, undeveloped cells may be prepared and used as stockpile areas to store overburden soils to be used during construction or for daily/interim cover stockpiles. This approach reduces the required area for the laydown and stockpile of materials. ■ A 30 m buffer is established along all identified wetlands near the NSDF site. ■ Erosion and sediment control practices (e.g., silt fences, runoff management) applicable to the region and already in place at the CNL property will be used during construction around disturbed areas, where appropriate. ■ During the construction phase, erosion and sediment control measures in place to mitigate the effects of sediment transport include the use of erosion control blankets, as needed, to control erosion on steep slopes, check dams in ditches and swale. ■ Surface water from all external areas will be conveyed by ditches, swales and culverts to surface water management ponds to address water quality and water quantity criteria established for the wetland receiving waters and, ultimately, Perch Creek. ■ Where drainage crosses roadways, culverts are sized to convey the 25-year design event without road overtopping. ■ The surface water management ponds are designed to address erosion and sediment control concerns during construction by providing interim sediment control and by providing water quality/quantity controls during operations, closure, and post-closure. ■ Annual maintenance activities will identify any erosion problems. ■ A maintenance review will be completed after major storm events and after the annual springmelt to confirm there are no major erosion issues.	Secondary
General Project activities during the operation phase	Discharge of treated domestic wastewater may cause a change in water levels, flows, and channel/bank stability at downstream locations.	■ The grey water/sewage will be stored in a holding tank at the NSDF Project site and periodically transferred to the CRL Sewage Treatment Plant.	Secondary

Table 5.4.1-9: Pathways Analysis for the Hydrology Valued Component

Project Activity	Effects Pathways	Management Practices and Mitigation Actions	Pathway Assessment
Project activities during the operations and closure phases: ■ Surface water management ■ Operation of the WWTP ■ Discharge of treated effluent from the WWTP	Discharge of treated effluent from the WWTP to the East Swamp Wetland may cause changes to water levels, flows, and channel/bank stability in downstream waterbodies, and water levels in the adjacent wetlands.	■ The strategy for wastewater treatment is based on optimizing public and environmental protection by defining an approach to wastewater treatment that uses best demonstrated available technology that is economically achievable (BDATEA), and capable of meeting regulatory requirements. ■ The treatment target for effluent is the CRL Acceptability Criteria for Routine and Non Routine Discharge of Liquids to Stormwaters.The effluent requirement for treated wastewater is the CRL Acceptability Criteria for Routine and Non Routine Discharge of Liquids to Stormwaters. ■ Treated effluent will be sampled and confirmed that it meets treatment before release to East Swamp Wetland ■ Appropriate procedures to identify emergency spill occurrences and response, as well as appropriate response to non-contact surface water or leachate contamination will also be implemented as described in the Operations and Maintenance Plan and Contingency Plan ■ Discharge of treated effluent to the exfiltration gallery area will help to reduce water loss from the hydrogeological system. ■ Outlet flows from all three surface water management ponds will be dispersed by level spreaders that will provide an even flow distribution to the wetland with an appropriately wide dispersal pattern. ■ The WWTP system's outlet utilizes a headwall which discharges to a level spreader for the purposes of preventing erosion and sedimentation at the outlet for the exfiltration gallery. ■ Current surface water management ponds outlet locations are limited by the site boundary (greater than 5 m separation required) so that there is no discharge from the spreader directly to the wetland. ■ Annual maintenance activities will identify any erosion problems. ■ A maintenance review will be completed after major storm events and after the annual spring melt to confirm there are no major erosion issues.	Secondary

Table 5.4.1-9: Pathways Analysis for the Hydrology Valued Component

Project Activity	Effects Pathways	Management Practices and Mitigation Actions	Pathway Assessment
Project activities during the closure and post-closure phases: ■ Installation of final ECM cover, restoration and grading of the site	The installation of the ECM will physically alter drainage patterns, and may change downstream discharge, water levels in adjacent wetlands, and channel/bank stability.	■ The final cover is designed to promote positive drainage from the NSDF Project site and reduce erosion or abrasion of the cover. ■ The final cover system will be constructed to promote the shedding of surface water to mitigate infiltration into the mound, and minimize leachate generation. ■ The cover system design incorporates a series of shallow, trapezoidal, riprap-lined drainage channels that are designed to convey water at low velocity. ■ The perimeter road ditch will route the runoff around the ECM perimeter to minimize ponding of water into the closed ECM, erosion of the cover and underlying waste materials, destabilization of the ECM structure, and damage to access roads. ■ The ECM final grading and drainage plan includes collection ditches along the top of the ECM berm road to collect side slope drainage. ■ Environmental monitoring will be completed throughout the post-closure phase for the NSDF Project to confirm that the cover is functioning as intended.	Primary

ECM = engineered containment mound.

5.4.1.6.1.1 No Linkage Pathways

No pathways were identified as having no linkage to effects on hydrology.

5.4.1.6.1.2 Secondary Pathways

The following pathways were assessed as potentially having a measurable minor environmental change, but negligible residual effect on the hydrology relative to Base Case.

Discharge of treated domestic wastewater may cause a change in water levels, flows, and channel/bank stability at downstream locations.

CNL's Sewage Treatment Plant receives approximately 700 m^3 of grey water/sewage per day from the approximately 2,500 staff on the CNL property. An additional workforce of 50 staff will be required for the NSDF Project (see Section 3.12), generating grey water/sewage rates within those observed currently on the CNL property. The grey water/sewage from construction and operation of the NSDF Project will be stored in a holding tank at the NSDF Project site and periodically transferred to the Sewage Treatment Plant. Discharge of treated domestic wastewater for the NSDF Project to downstream locations (e.g., Ottawa River) will not cause a change in water levels, flows, and channel/bank stability from current conditions. Therefore, this pathway was determined to have no linkage to effects on hydrology.

The construction of the NSDF Project will physically alter drainage patterns in the Perch Lake watershed, and may change downstream discharge, water levels, and channel/bank stability, and water levels in adjacent wetlands.

The surface water management ponds are designed to address erosion and sediment control concerns during construction by providing interim sediment control and by providing water quality/quantity controls during operations, closure, and post-closure. The current surface water management pond footprints reflect the overall storage required to control post-closure flows to predevelopment levels for the 2-year through to 100-year rainfall events at the site. This volume also contains the storage required for sediment control during construction and water quality control during operations. The target surface water quality objective is provided by MOECC in Stormwater Management Planning and Design Manual (MOECC 2003), which reports a 60% total suspended solids (TSS) removal that provides a basic water quality treatment for discharge to the receiving wetland.

During the construction phase, erosion and sediment control measures will be in place to mitigate the effects of soil erosion and sediment transport. The measures include the use of erosion control blankets, as needed, to control erosion on steep slopes, check dams in ditches and swales, and the three proposed surface water management ponds that will be constructed to serve as interim sediment control facilities during construction, and then as stormwater management facilities during the operations, expansion and post-closure periods. Erosion and sediment control practices (e.g., silt fences, runoff management) applicable to the region and already in place at the CRL property (i.e., CNL's Management of Land and Habitat Procedure) will be used around disturbed areas, where appropriate.

Site operations include surface water management for the ECM and all external areas. Surface water from all external areas will be conveyed by ditches, swales and culverts to surface water management ponds that will address water quality and water quantity criteria established for the wetland receiving waters and, ultimately, Perch Creek. Contact surface water drainage from the active cells of the ECM will be to the WWTP. Non-contact surface water drainage from completed cells and yet-to-be-activated cells will be directed either by gravity to the external

surface water management system or to temporary holding ponds within the ECM, or then pumped to the three surface water management ponds. There will be a need to address pre-treatment of surface water run-off from the active cells prior to conveyance to the WWTP and a need to establish conveyance mechanisms (gravity and pumping) from the interior of the ECM to the surface water management ponds.

Facility inspections will be completed twice annually to confirm that inlets and outlets are clear of debris and to confirm that there are no major erosion issues at the inlet or outlet. As well, the integrity of berms and outlet structures will be confirmed by visual inspections that would identify any animal burrowing activity or active soil erosion. Inspections will identify sediment clean-out requirements. Sediments will be extracted by excavation equipment and will be disposed of based on sediment sampling, testing, and classification according to MOECC standards or stockpiled, de-watered and re-used on-site for ECM cover operations. The sediment removal assessment follows procedures identified in the Stormwater Management Planning and Design Manual (MOECC 2003).

All proposed physical works are located within the SSA, affecting a relative small area (4.1%) of the total contributing basin area for Perch Creek (720 ha; Robertson and Barry 1985). Any changes to existing drainage patterns will largely be restricted to this small sub-basin. Furthermore, all non-contact and contact surface water will be managed within the NSDF Project site, as per the Surface Water Management Plan that will be developed, reducing the potential for the NSDF Project to affect downstream discharge, water levels, and channel/bank stability. Overall, changes to downstream discharge, water levels, and channel/bank stability resulting from construction of the NSDF Project will be localized to the receiving wetland. Therefore, this interaction was determined to have a negligible residual effect on hydrology.

Discharge of treated effluent from the WWTP to the East Swamp Wetland may cause changes to water levels, flows, and channel/bank stability in downstream waterbodies, and water levels in the adjacent wetlands.

A Surface Water Management Plan will be implemented to mitigate impacts on surface water from contact surface water, where contact water is that exposed to contaminated waste within the engineered containment mound (ECM). Most of the wastewater flow will be generated from contact stormwater produced during active filling of the ECM; contributions by leachate and decontamination activities represent a small fraction of the overall wastewater that will be treated by the WWTP. The total annual volume of contact surface water to be treated is 6,556 m^3. The volume represents approximately 0.38% of the average total outflow from Perch Lake (1,700,000 m^3 per year), or 0.30% of the average total outflow from Perch Creek (2,200,000 m^3 per year). Operational treated effluent discharge is expected to be less than 1 cubic metres per hour (m^3/hr). Flow rates within Perch Creek are approximately 252 m^3/hr; the effluent discharge rate is roughly 0.4% of the average Perch Creek flows and approximately 11.5% of East Swamp Weir flows. Furthermore, the receiving wetlands are expected to buffer the discharge, further reducing flow rates into Perch Creek.

The major flow system for all three surface water management ponds will outlet to the adjacent wetland and will be dispersed by level spreaders that will provide an even flow distribution to the wetland with an appropriately wide dispersal pattern. The WWTP outlet use a headwall that discharges to a level spreader for the purposes of preventing erosion and sedimentation at the outlet. An exfiltration gallery is proposed at the discharge outlet to promote the exfiltration of treated water into the local groundwater regime. Current surface water management ponds outlet locations are limited by the site boundary (greater than 5 m separation required) so that there is no discharge from the spreader directly to the wetland. Local topography between the level spreader and the wetland,

as well as any setbacks, has influenced the location of the level spreader on site. Annual maintenance activities will identify any erosion problems. Facility inspections will be completed twice annually to confirm that inlets and outlets are clear of debris and to confirm that there are no major erosion issues at the inlet or outlet. In addition, a maintenance review will be completed after major storm events and after the annual spring melt to confirm there are no major erosion issues at the dispersion outlets. Overall, changes to downstream discharge, water levels, and channel/bank stability resulting from operational discharges of water from the WWTP will be localized to the receiving wetland. Therefore, this interaction was determined to have a negligible residual effect on hydrology.

5.4.1.6.1.3 Primary Pathways

The following primary pathway was identified as having residual effects on hydrology, and is therefore, carried forward to the residual effects analysis.

- The installation of the ECM will physically alter drainage patterns, and may change downstream discharge, water levels in adjacent wetlands, and channel/bank stability.

5.4.1.7 Residual Effects Analysis

5.4.1.7.1 Methods

The design of the surface water management ponds and associated systems use standard surface water management principles by controlling erosion, capturing sediment, and allowing infiltration of non-waste contact surface water. The current surface water management pond footprints reflect the overall storage required to control post-closure flows to predevelopment levels for the 2-year through to 100-year rainfall events at the site. This volume also contains the storage required for sediment control during construction and water quality control during operations. Where drainage crosses roadways, culverts are sized to convey the 25-year design event without road overtopping. Three surface water management ponds provide both quality and quantity control during construction, operations and closure phases. Flows from the ponds will be dispersed by a form of level spreader to provide even flow distribution to the wetland with an appropriate dispersal pattern to limit erosion and scouring of the wetland.

Closure activities include the installation of an engineered cover over the ECM to limit ponding and water infiltration in to the waste. The final cover system will be constructed at slopes between 5% (overall slope for the top slope portion of the cover) and 25% (4H:1V) for the side slope portion of the cover. The top slopes and side slopes of the final cover are designed to be flat enough to satisfy slope stability factor of safety criteria and erosion control criteria. Modification to the drainage ditches and conveyance channels will be made to promote positive drainage from the site and limit erosion or abrasion of the cover. Run-off control for the cover is designed to limit ponding and infiltration of water into the ECM, erosion of the cover and waste material, and destabilization of the structure. The ECM design approach is to control the direction and velocity of the run-off to prevent erosion and abrasion of the cover. During the closure phase, surface water within the extents of the ECM will no longer be conveyed to the WWTP but will be conveyed through a series of riprap-lined channels and downdrains into the ECM perimeter road ditch which drains into surface water management ponds #2 and #3 before being discharged to the wetland receiving waters and ultimately, Perch Creek.

The collection, conveyance and / or detention of runoff for the NSDF Project site upon closure of the ECM was modelled using Visual Otthymo 4.0 software for 1:2 year, through to the 1:100 year storm events; the Timmins Storm (Regional Event) was also modelled. Rainfall intensity data was sourced from the Town of Arnprior.

5.4.1.7.2 Application Case Results

Table 5.4.1-10 provides a comparison of pre-development (i.e., Base Case) and controlled post development (i.e, closure phase) run off rates. Modelling results show an overall increase in run-off rates in the northern section of the NSDF Project site and discharging from the surface water management pond #1 area; conversely, decreases are predicted in the discharge rates from the surface water management ponds #2 and #3 areas. An increase of 1.1 ha is also predicted for the surface water management pond #1 catchment area in the post development condition. Overall, the results show that the surface water management system is designed so that flows during the closure phase are controlled to pre-development levels (Table 5.4.1-10); thus preventing increased erosion rates in the receiving water bodies due to increased discharge rates.

Table 5.4.1-10: Comparison of Peak Discharge Rates Pre-development versus Post-development

Stormwater Pond	Peak Runoff Rates	Storm Event			
		1:2 Year	1:5 Year	1:100 Year (24 hr duration)	Timmins Storm (12 hour 193 mm)
SWMP #1	Pre-development	0.03 m^3/s	0.07 m^3/s	0.21 m^3/s	0.23 m^3/s
	Post-development	0.11 m^3/s	0.21 m^3/s	0.72 m^3/s	0.90 m^3/s
SWMP #2	Pre-development	0.11 m^3/s	0.22 m^3/s	0.66 m^3/s	0.65 m^3/s
	Post-development	0.10 m^3/s	0.21 m^3/s	0.64 m^3/s	0.88 m^3/s
SWMP #3	Pre-development	0.02 m^3/s	0.05 m^3/s	0.15 m^3/s	0.18 m^3/s
	Post-development	0.02 m^3/s	0.05 m^3/s	0.13 m^3/s	0.22 m^3/s

5.4.1.8 Prediction Confidence and Uncertainty

The hydrologic model is considered to provide a reasonable prediction of the current stormwater run-off rates and volumes, as well as the increases expected due to development of the site. The surface water runoff was modelled using Visual Otthymo 4.0 software for the 2-year through to 100-year rainfall events and the regional storm event for the area (i.e., The Timmins Storm) was also modelled along with the probable maximum precipitation (PMP). Visual Otthymo is a hydrologic management model that is capable of simulating run-off from single storm events. It is well suited to hydrologic studies of watersheds and sub-watersheds and is a useful tool in creating master drainage plans, site stormwater designs and surface water management design. Rainfall intensity data inputted into the model was sourced from the Town of Arnprior as the storm data was more recent than that available from Environment Canada for the area. This rainfall distribution is a synthetic distribution and presents a heavy front loaded storm with reduced infiltration leading to higher run-offs than may be seen with intensities more evenly distributed throughout the storm. This results in conservative model outputs with the resultant stormwater management systems capable of handling larger storm events than those modelled.

5.4.1.9 Monitoring and Follow-up

Monitoring and follow-up programs for hydrology are related to operational monitoring (i.e., verify the surface water management ponds are performing as designed) and environmental monitoring (i.e., confirm that the ecological function and structure of the wetland system is maintained; Table 5.4.1-11).

Table 5.4.1-11: Monitoring and Follow-up Programs for Hydrology

Valued Component	Project Phase and Potential Effect	Monitoring Program Objective	Conceptual Monitoring Program	Suggested Duration	Implementing Program
Hydrology	The installation of the ECM will physically alter drainage patterns, and may change downstream discharge, water levels in adjacent wetlands, and channel/bank stability.	Operational monitoring – Verify the surface water management ponds are performing as designed.	Support the development of hydrographs of surface water management pond inflow and outflow. Outflow would be based on theoretical stage-discharge rating curves for weir and orifice outlets and inflow based on routing that uses stage-storage and stage-discharge curves for the particular surface water management pond in question.	The water level at the surface water management pond will be monitored during construction and operation. The need for and duration of monitoring will be reviewed based annual review of monitoring data.	Integrated into the NSDF Project Environmental Protection Plan to be developed and implemented for the NSDF Project.
		Environmental monitoring – Confirm that the ecological function and structure of the wetland system is maintained.	Monitoring of wetland water elevations to determine changes from the presence of the ECM.	Water level monitoring of the wetland system will be initiated pre-construction (baseline) and continue through construction and operations. The need for and duration of monitoring will be reviewed based annual review of monitoring data.	Water-level monitoring of the wetland system will be integrated into the CNL Environmental Monitoring Program.

5.4.1.10 Conclusions

Valued components refer to environmental features that may be affected by a project and that have been identified to be of concern by the proponent, scientists, government agencies, Aboriginal peoples, or the public (The Agency 2014). Hydrology, which includes surface water quantity, flow and direction, is recognized as an important component of the environment that may be affected by the NSDF Project and changes to hydrology could, in turn, lead to effects on other VCs selected for assessment. Acknowledging that changes to hydrology are considered to be important aspects of the natural and human environment, hydrology is referred to as an intermediate component. Results of the analysis of changes in measurement indicators for hydrology are provided to other disciplines for inclusion in their assessment.

All physical works are located within the NSDF Project site, affecting a relative small area (4.1%) of the total contributing basin area for Perch Creek (720 ha). The total annual volume of contact surface water to be treated is 6,556 m^3. The volume represents approximately 0.38% of the average total outflow from Perch Lake (1,700,000 m^3 per year), or 0.30% of the average total outflow from Perch Creek (2,200,000 m^3 per year). Operational treated effluent discharge is expected to be less than 1 cubic metres per hour (m^3/hr). Flow rates within Perch Creek are approximately 252 m^3/hr; the effluent discharge rate is roughly 0.4% of the average Perch Creek flows and approximately 11.5% of East Swamp Weir flows. Furthermore, the receiving wetlands are expected to buffer the discharge, further reducing flow rates into Perch Creek.

Residual effects to the hydrology VC are primarily associated the eventual closure of the NSDF Project, which will physically alter drainage patterns in the Perch Creek basin. The main physical works related to the NSDF Project is the ECM, the WWTP, and supporting infrastructure. The design of the surface water management ponds and associated systems use standard surface water management principles by controlling erosion, capturing sediment, and allowing infiltration of non-waste contact surface water. The current surface water management pond footprints reflect the overall storage required to control post-closure flows to predevelopment levels for the 2-year through to 100-year rainfall events at the site. Where drainage crosses roadways, culverts are sized to convey the 25-year design event without road overtopping.

Closure activities include the installation of an engineered cover over the ECM to limit ponding and water infiltration in to the waste. Modification to the drainage ditches and conveyance channels will be made to promote positive drainage from the site and limit erosion or abrasion of the cover. During the closure phase, surface water within the extents of the ECM will no longer be conveyed to the WWTP but will be conveyed through a series of riprap-lined channels and downdrains into the ECM perimeter road ditch which drains into surface water management ponds #2 and #3 before being discharged to the wetland receiving waters and ultimately, Perch Creek. Modelling results show that the surface water management system is designed so that flows during the closure phase are controlled to pre-development levels; thus preventing increased erosion rates in the receiving water bodies due to increased discharge rates.

Monitoring and follow-up programs for hydrology are related to operational monitoring (i.e., verify the surface water management ponds are performing as designed) and environmental monitoring (i.e., confirm that the ecological function and structure of the wetland system is maintained.

Table 5.4.1-12: Summary of Predicted Residual Adverse Effects for Hydrology Valued Components

Valued Component	Residual Adverse Effects	Project Effect Occurs in	Contributing Project Activity	Proposed Mitigation
Hydrology	The installation of the final cover of the ECM and decommissioning of infrastructure will physically alter the Perch Lake watershed area and drainage patterns, and may change downstream discharge, water levels, and channel/bank stability, and water levels in adjacent wetlands.	Closure and Post-closure	■ Installation of the final cover of the ECM, restoration and grading of the site ■ Continued operation of surface water management structures	■ The final cover is designed to promote positive drainage from the NSDF Project site and reduce erosion or abrasion of the cover. ■ The final cover system will be constructed to promote the shedding of surface water to mitigate infiltration into the mound, and minimize leachate generation. ■ The cover system design incorporates a series of shallow, trapezoidal, riprap-lined drainage channels that are designed to convey water at low velocity. ■ The perimeter road ditch will route the runoff around the ECM perimeter to minimize ponding of water into the closed ECM, erosion of the cover and underlying waste materials, destabilization of the ECM structure, and damage to access roads. ■ The ECM final grading and drainage plan includes collection ditches along the top of the ECM berm road to collect side slope drainage. ■ Environmental monitoring will be completed throughout the post-closure phase for the NSDF Project to confirm that the cover is functioning as intended.

5.4.2 Surface Water Quality

5.4.2.1 Scope of the Assessment

Section 5.4.2 focuses on surface water quality and follows the overall environmental assessment approach and methods described in Section 5.1. The assessment is completed in the following seven primary steps:

- **Step 1 – Identify Valued Components (VCs) and define the spatial boundaries, temporal boundaries, and assessment cases** for the surface water quality assessment (refer to Sections 5.4.2.2 Valued Components and Section 5.4.2.3 Assessment Boundaries). The VCs and measurement indicators used to assess NSDF Project-related changes to surface water quality, the spatial and temporal boundaries at which the assessment occurred, and the assessment cases considered are described.
- **Step 2 – Describe the existing conditions** (refer to Section 5.4.2.4 Description of the Environment). Existing conditions in the local and regional areas are described, including the combined effects of previous and existing developments (Base Case). The existing environment represents the historical and current environmental pressures that have shaped the observed patterns in the environment (i.e., natural variation).
- **Step 3 – Evaluate Project interactions and mitigation** (refer to Section 5.4.2.5 Project Interactions and Mitigation). NSDF Project components and/or activities with the potential to affect surface water quality are identified and mitigation developed to limit or avoid effects is presented. A pathways analysis is then used to focus further assessment on key interactions between the NSDF Project and the environment by evaluating the different effect pathways to determine if, after incorporation of mitigation, there is still potential to cause residual effects to surface water quality. Where effects are adequately mitigated and do not require further analysis (i.e., where mitigation removes the pathway altogether and limits the effects to minor changes), rationale for concluding the assessment at this stage is articulated. Primary pathways that may lead to residual effects to surface water quality after incorporating mitigation are carried forward to Step 4 for further analysis and residual effects characterization.
- **Step 4 – Present the methods and results of the residual effects analysis** (refer to Section 5.4.2.6 Residual Effects Analysis). The residual effects analysis section outlines the methods used to predict and characterize residual effects to surface water quality from primary effect pathways. The analysis results are also presented including the characterization of incremental effects from the NSDF Project, as well as cumulative effects of the NSDF Project in combination with other reasonably foreseeable developments (if applicable). A key outcome of this section is the predicted changes to surface water quality that are passed on to other disciplines for their assessment.
- **Step 5 – Describe the level of certainty and management of uncertainty** (refer to Section 5.4.2.7 Prediction Confidence and Uncertainty). The prediction confidence and uncertainty section evaluates the available literature, data, and models used for the assessment, and describes the level of certainty that can be placed on predicted residual effects. This section will also identify how the uncertainty has been managed so that the effects are not underestimated.
- **Step 6 – Identify monitoring and follow-up** required to confirm effects predictions and address uncertainty (refer to Section 5.3.2.8 Monitoring and Follow-up).
- **Step 7 – Present a consolidated summary of conclusions and outcomes of the assessment** of residual effects on surface water quality (refer to Section 5.4.2.9 Conclusions).

Section 5.4.2 also describes how the input from engagement influenced the scope of the surface water quality assessment. Information and areas of interest raised by the public, communities of interest, regulators, and First Nations and Métis communities during engagement that influenced the scope of the surface water quality assessment are summarized in Table 5.4.2-1. Other general areas of interest and questions raised during the engagement that pertain to the surface water quality assessment (if any) are documented in Appendix 4.0-22 Formal Public Feedback.

Table 5.4.2-1: Summary of Areas of Interest Raised During Engagement Activities that Influenced the Scope of the Surface Water Quality Assessment

Areas of Interest	How the Area of Interest was Included in the Assessment
Potential for contamination in the Ottawa River from the NSDF Project.	The spatial boundaries of the assessment were selected to include consideration of potential effects to the Ottawa River. Surface water quality modelling was completed to estimate contaminant concentrations within the Perch Creek basin, which flows directly into the Ottawa River. Meeting site-specific treatment targets within the Perch Creek basin is considered to be protective of the Ottawa River.

5.4.2.2 Valued Components

Valued components (VCs) refer to environmental features that may be affected by a development and that have been identified to be of concern by the proponent, scientists, government agencies, First Nation and Métis peoples, or the public (The Agency 2014). Surface water quality is recognized as an important component of the environment that may be affected by the NSDF Project and changes to surface water quality could, in turn, lead to effects on other VCs selected for assessment. For example, changes to the characteristics of surface water quality have a large influence on aquatic, human, and wildlife health. Subsequently, changes to these characteristics by NSDF Project activities could affect aquatic organisms and the use of water as a drinking water source for people or wildlife (Table 5.4.2-2). The assessment of surface water quality focused on predicting changes in the concentrations of selected non-radiological parameters to the receiving environment as a result of the Project. Changes to radiological parameters are discussed in Section 5.7 Ambient Radioactivity.

Acknowledging that changes to surface water quality are considered to be important aspects of the natural and human environment, surface water quality is referred to as an intermediate component (i.e., it does not have an assessment endpoint). Changes to intermediate component VCs must be understood to facilitate assessment of Project interactions. The surface water quality assessment, therefore, is analyzed for incremental and cumulative (if applicable) changes in the relevant measurement indicators associated with surface water quality (Table 5.4.2-3). The changes are characterized in terms of magnitude, duration, and geographic extent, but they are not classified using rankings for effects criteria. For example, the magnitude of change in a water quality parameter may be described as the relative change from baseline; however, this change would not be classified (or ranked) as low, moderate, or high. The surface water quality assessment also does not include the assessment of the significance of these changes; rather, assessment results for surface water quality (i.e., projected changes in water quality measurement indicators) are provided to other disciplines for inclusion in their assessment (Table 5.4.2-3).

Table 5.4.2-2: Valued Components for the Surface Water Quality Assessment

Valued Component	Rationale for Selection
Surface Water Quality	■ Water quality to support aquatic and human health is defined by the concentration or value of various physical and chemical constituents [(a)] of water, such as temperature, suspended particulate matter, major ions (e.g., chloride, potassium), nutrients (e.g., nitrogen, phosphorus), metals and trace organic compounds that occur in dissolved or soluble form (e.g., aluminum and iron), and suspended matter (comprising inorganic or organic material). ■ Changes in the quality of water can affect aquatic and terrestrial sustainability and biodiversity, and the use of water for recreational purposes or as a drinking water source for people, and a drinking water source for wildlife. ■ Societal values concerning changes in water quality are an important consideration in understanding potential effects of the NSDF Project.

(a) the surface water quality assessment addresses only the non-radiological constituents of water; the assessment of radiological constituents is provided in Section 5.7 Ambient Radioactivity.

Table 5.4.2-3: Measurement Indicators for the Surface Water Quality Assessment

Valued Component	Measurement Indicators	Discipline Assessments where Effects on Surface Water Quality are Considered
Surface Water Quality	Concentrations of non-radiological constituents in surface water, which will be compared to baseline concentrations and site-specific treatment targets.	■ Section 5.5 Aquatic Biodiversity ■ Section 5.6 Terrestrial Biodiversity ■ Section 5.8 Human Health

5.4.2.3 Assessment Boundaries

5.4.2.3.1 Spatial Boundaries

The spatial boundaries selected for the surface water quality assessment were chosen because they permit description of existing conditions in sufficient detail to enable potential project-VC interactions and effects to be identified, understood, and assessed, including understanding and assessing the contribution of the NSDF Project to cumulative effects. The spatial boundaries selected for the surface water quality are consistent with the hydrology and aquatic biodiversity assessment are presented on Figure 5.4.1-1 and are described below:

- **Site Study Area (SSA):** the SSA is the NSDF Project footprint (i.e., where project activities would be undertaken including the NSDF Project's proposed facilities, buildings and infrastructure).
- **Local Study Area (LSA):** The LSA is defined as the area within which there is potential for measurable changes to measurement indicators resulting from the proposed NSDF Project activities. The LSA includes the SSA and is bounded by Perch Lake and Perch Creek, and adjacent wetlands and swamps.
- **Regional Study Area (RSA):** The RSA is defined as the area within which the potential effects of the NSDF Project may interact with the effects of other existing or reasonably foreseeable projects. The RSA for hydrology is determined by the spatial extent of the Perch Lake watershed, and includes Perch Lake and its tributaries, and Perch Creek. Although the Ottawa River in the vicinity of the mouth of Perch Creek is included in the RSA, the river beyond this location lies outside the boundary of the assessment.

5.4.2.3.2 Temporal Boundaries

Temporal boundaries (i.e., project phases) establish the timeframe during which NSDF Project effects are assessed. The temporal boundary represents the timeframe during which project activities are actively occurring, and considers the duration of predicted residual effects. The duration of an effect is defined as the amount of time between the start and end of a Project activity or stressor (which is related to the project phases) plus the time required for the residual effect to be reversed. In some cases, a residual effect may be irreversible within the temporal boundaries of the Project or if the effects were predicted to last so far into the future that they could not be predicted with any level of certainty (e.g., residual effect lasts for thousands of years). The following phases were identified for the NSDF Project:

- **Construction Phase**: includes site preparation and all activities associated with the construction of the NSDF. This phase includes activities such as installing the necessary supporting and/or ancillary facilities and NSDF infrastructure to facilitate NSDF operations, inactive commissioning and systems testing, and transportation of construction materials. Construction activities are expected take place from 2018 to 2020.
- **Operations Phase**: includes all activities associated with the landfilling of waste receipt, waste placement, water management, wastewater treatment plant operations, vehicle movements into and from the NSDF Project site, and maintenance activities. Operations activities are expected to last approximately 50 years (i.e., 2020 to 2070).
- **Closure Phase:** includes activities necessary to complete the installation of the final cover and implementation of long-term monitoring. Closure activities are expected to start in 2070 and continue through to 2100, after which the NSDF Project will transfer into the post-closure phase.
- **Post-closure Phase:** has two discrete periods: Institutional Control and post-Institutional Control. The Institutional Control period includes implementation of both active and passive control throughout 2100 to 2400 (i.e., 300 years). During Institutional Control, groundwater monitoring and groundwater quality management will continue to demonstrate compliance with the safety case assumptions. Post-institutional Control occurs after year 2400 and continues indefinitely.

The temporal boundaries for the surface water quality assessment include consideration of effects of the NSDF Project during the operations and post-closure phases.

5.4.2.3.3 Assessment Cases

The assessment cases considered in the surface water quality assessment include the Base Case and Application Case:

- **Base Case –** This scenario represents existing conditions and characterizes combined effects from previous and existing developments and activities. The Base Case reflects the effects of existing disturbances, such as forestry, transportation, agricultural, mining, and residential and recreational development. Current effects from the existing CRL facilities and operations, for example, are considered part of the Base Case.
- **Application Case –** This scenario represents predictions of the effects of the Base Case combined with the effects that may result from the NSDF Project. The Application Case considers potential effects from the NSDF Project during construction through to the closure and post-closure phase.

Reasonably Foreseeable Development (RFD) Case – This scenario represents predictions of the cumulative effects of the Application Case, which includes the Base Case, plus projects that are currently under application review or that have officially entered a regulatory application process, and are therefore, considered reasonably foreseeable. New support infrastructure and research and development facilities will be located within existing disturbed areas on the CRL property (i.e., no disturbance to Greenfield areas). Potential effects from these activities are not expected to spatially overlap with potential effects to surface water quality from the NSDF Project. The NSDF Project will enable the remediation of contaminated lands and legacy waste management areas, and decommissioning of outdated infrastructure at the CRL property and CNL's other business locations to support future CNL missions. The end-state plan for the CRL site will be to return lands disturbed by site activities to a condition that is physically stable, and safe in keeping with the land use and landscape of the day. Therefore, decommissioning and environmental restoration activities are anticipated to positively affect surface water quality. Because RFDs will either have no spatial overlap or are likely to positively affect the surface water quality, an RFD Case is not presented as part of this assessment.

5.4.2.4 Description of the Environment

Surface water is monitored at on-site lakes and streams, off-site streams, and locations in the Ottawa River both upstream and downstream of the CRL property (Figure 5.4.1-1). Sample collection of non-radioactive parameters under CRL's Environmental Monitoring Program is in accordance with the CRL Non-Radiological Monitoring Program Sampling Protocol (CRL 2013) and approved methods in the Protocol for the Sampling and Analysis of Industrial/Municipal Waste Water (also referred to as the Municipal/Industrial Strategy for Abatement [MISA2] protocol; MOECC 2003), with minor modifications. Regional and local surface water quality data described in the *Chalk River Laboratories: A Description of the Environmental Baseline for Environmental Assessments* (AECL 2008), and in the *Environmental Monitoring in 2015 at Chalk River Laboratories* (CNL 2016a) are included in the following sections (for more details see Appendix 5.4-2). The available baseline conditions for Perch Lake and Perch Creek are also summarized.

5.4.2.4.1 Ottawa River

The CRL property, as well as the surrounding area, is located entirely within the Ottawa River watershed. The Chalk River and Petawawa Rivers are the two major downstream tributaries near the CRL property. Approximately 18% of the CRL property flows through Perch Creek and subsequently into the Ottawa River (CNL 2016a), and includes the CRL Built-Up Area Basin of the CRL property, where most of the operational nuclear and industrial facilities are located. The CRL Built-Up Area Basin also includes several landfill facilities, including the Inactive Landfill which is currently in operation, and two groundwater contaminant plumes from the National Research Experimental (NRX) and National Research Universal (NRU) reactor facilities that slowly discharge to the Ottawa River through regions of the riverbed. Wastewater effluents and streams with the potential to release contaminants to the Ottawa River are subject to routine monitoring, as appropriate, providing a means of measuring and controlling releases to the environment (CNL 2016a).

A list of non-radiological constituents of potential environmental concern for the CRL site are provided in Appendix 5.4-2, Table 1 (source AECL 2008). Non-radiological parameter values for Ottawa River water are available from sampling at two locations adjacent to the CRL property (CRL water intake and Gray Dock) and at several locations upstream and downstream of the CRL property. Sampling locations include Stonecliffe (45 km upstream), Rolphton (26 km upstream), Perch Creek outfall, Pointe au Baptême at the CRL downstream property boundary, and Petawawa.

Based on 2002-2003 data, iron and mercury concentrations at the CRL water intake were measured above the Ecological Effects Review (EER) benchmark in Appendix 5.4-2, Table 2 (source EcoMetrix Inc. 2005). Furthermore, cadmium, copper, and zinc concentrations elsewhere in the Ottawa River were occasionally measured above EER values. The range of concentrations reported for the select water quality parameters provided in Table 2 characterize the natural background concentrations in the Ottawa River at locations in the proximity of the CRL development. Measurable incremental effects on the water quality in the Ottawa River is not expected (AECL 2010).

The nearest Provincial Water Quality Monitoring Network (PWQMN) station (18493002002) is located on the Ottawa River approximately 16 km southeast (downstream) of Perch Lake on Highway St. in Petawawa (Latitude 45°54'13"N; Longitude 77°17'8"W). The data record for this station is from 1968 to 2000. The Mattawa River PWQMN station (18607002002) is an active station that first sampled in 1968 and is situated approximately 108 km northeast of Perch Lake along the Highway 533 bridge (Latitude 46°19'7"N; Longitude 78°42'25") just before its confluence with the Ottawa River. Due to the lack of PWQMN stations near the Perch Creek confluence, PWQMN data are not applicable in establishing existing surface water quality conditions for the RSA. Ottawa River water quality for select metals (i.e., those that possess EER benchmarks) at the CRL water intake is summarized in Table 5.4.2-4 (AECL 2010).

Table 5.4.2-4: Summary of Ottawa River Quality at the CRL Water Intake

Parameter	Units	EER Benchmarks	CRL Water Intake[a,b,c]
Cadmium	µg/L	0.15	<0.8
Copper	µg/L	2	1 to 4.5
Iron	mg/L	0.3	0.15 to 0.37
Lead	µg/L	18.8	<2 to <10
Mercury	µg/L	0.23	0.02 to 0.035
Zinc	µg/L	30	6 to 10

(a) Range from quarterly sampling performed in 2003.

(b) Mercury data from quarterly sampling in 2002.

(c) Less-than symbol indicates less than Lower Limit of Detection (LLD).

5.4.2.5 Perch Lake Watershed

The NSDF Project is located entirely within the Perch Lake and Perch Creek drainage basins in the RSA, which drain to the Ottawa River (Figure 5.4.1-2). This drainage basin contains many of the site's operating WMAs and in particular the WMAs of the earliest vintage in the evolution in waste storage practices at CRL, including the Liquid Dispersal Areas (LDAs). Because of its history, this basin is the most affected region of the CRL Supervised Area.

Physical characteristics of Perch Lake include a wetted area of approximately 45 ha, a drainage area of 730 ha, a maximum depth of 3.5 m, and a mean depth of 2 m (Robertson and Barry 1985). Most of Perch Lake is open water except for littoral zones along the shore, including a region of floating, emergent and submerged vegetation which amounts to about 30% of the lake's surface (Yankovich et al. 2000). The outer fringe of this zone is known as Perch Lake Marsh. This open marsh may be considered to be part of the lake, with which it is physically continuous. To the north, there are extensive wetlands, notably Perch Lake Swamp, South Swamp, East Swamp, and West Swamp. The lake is confined in part by sand outcrops along the northern and southern shores, and by bedrock along the western shores. The hydrology of Perch Lake has remained relatively constant over the past 30 years, and as such it is anticipated that the physical characteristics of the lake have not appreciably been modified.

Perch Lake is characterized by high levels of nutrients (Yankovich et al. 2000), and is described as dystrophic-eutrophic because it shows clear signs of nutrient enrichment, with approach to maturity in lake evolution. The highly-coloured water of Perch Lake has a pH of 5.5 to 6.8 and a low total suspended solids (TSS) content. The colour of the water is the result of humic and fulvic acids. On average, the lake is frozen from late-November to April. Following melting of the ice, the water warms up rapidly and summer temperatures can exceed 30°C; the highest temperature recorded was 34°C. During summer, the deeper parts of the lake become stratified with surface water temperatures about 5°C higher. The bottom waters of Perch Lake often become depleted in oxygen in summer and in winter, but without reaching full anaerobic conditions; no massive fish kills have been observed during these conditions.

Perch Creek is the dominant surface water feature that drains the Perch Creek basin directly into the Ottawa River. The upper third of Perch Creek is characterized by a low gradient, supporting extensive emergent vegetation and a thick layer of organic detritus. Below the Perch Creek weir, there is substantial increase in both overhead riparian cover and stream gradient. A series of small waterfalls (or cascades) and riffle-run sequences grade into slow-flowing water in the lower reach of the creek. Substrate is predominately rock, gravel, and coarse in the middle section of the creek, transitioning to a dominance of finer grained material (e.g., silt) in the lower reach of the creek.

Surface water sampling locations are monitored routinely throughout the Perch Creek basin (Figure 5.4.1-1). Monitoring data for a range of select physical, inorganic, and organic parameters (for which benchmark values have been established; Appendix 5.4-2, Table 3) for these sampling locations are provided in Appendix 5.4-2, Tables 4 to 11. Of the sampling locations, one provides reference water quality data for the basin, located at Inlet 4 along the southern perimeter of Perch Lake (PL4), as this location has not been affected by CNL operations. The closest monitored surface waters to the NSDF Project site are the East Swamp Weir (ESW), Perch Lake Inlet #2 (PL2), Perch Lake Outlet (PLO), and Perch Creek Weir (PCW; Figure 5.4.1-1). The ESW location is located immediately west of the NSDF Project site. This monitoring location is downstream of the CRL Liquid Dispersal Area, Laundry Pit, Reactor Pit 2, and Chemical Pit. The PL2 monitoring location is further downstream, and receives discharge from the East Swamp Stream, South Swamp Stream, and Main Stream. The PLO and PCW monitoring stations represent downstream locations at the exit point of Perch Lake, and along Perch Creek, which flows from Perch Lake to the Ottawa River.

In order to assess the impacts of non-radiological contaminants and physical stressors on surface water quality, the monitoring results were screened against the Benchmark Values (BVs) listed in Appendix 5.4-2, Table 3 (source CNL 2016a). The BVs represent the level above which ecological effects could potentially occur. For non-radioactive contaminants, BVs consist of either generic toxicological benchmarks or provincial and federal water quality guidelines. In cases where a BV is lower than the detection capability of the analytical method, any result that is below a detection limit is categorized as an exceedance. Exceedance of a BV does not necessarily indicate that ecological effects would occur, but instead indicates that there may be some potential for ecological effects (CNL 2016a).

Metals including copper, aluminum, iron, and uranium have been closely monitored in surface waters of the CRL site (from 2010 to 2015) because they have been found to be present at higher concentrations compared to previously established benchmark values (where copper = 2.0 micrograms per litre (µg/L), aluminum = 460 µg/L, iron = 300 µg/L, and uranium = 15 µg/L; see Appendix 5.4-2, Table 3). In 2015, the benchmark values (BV) for pH (6.5 to 9.0), copper, aluminum, iron, and uranium were exceeded in several instances in the Perch Creek basin (see Appendix 5.4-2, Tables 4 to 11). In most cases, with the exception of iron and uranium in some instances, these metals were present at concentrations similar to those seen in reference (i.e., unaffected) monitoring locations in the Perch Creek basin (CNL 2016a). Of the exceedances in 2015, iron concentrations were consistently above its BV at all monitoring locations; copper concentrations were consistently above its BV at the monitoring locations (except MSC); uranium concentrations were above its BV at PL1, PL2, and MAR, and aluminium concentrations were above its BV at ESW (see Appendix 5.4-2, Table 6 and 8, respectively). Notably high iron and uranium concentrations have been routinely measured at PL2 and ESW. All other parameters were present at levels comparable to those observed in previous years and at the reference locations (i.e., No Name Lake and Perch Lake Inlet 4) and are considered to be naturally occurring in the area. The exceedances can likely be attributed to variability in naturally elevated background concentrations; however, trends will continue to be monitored closely to confirm this.

5.4.2.6 *Project Interactions and Mitigation*

5.4.2.6.1 Methods

This section describes the process by which interactions between NSDF Project components and activities and surface water quality were identified and evaluated. Potential effect pathways are identified and mitigation developed to eliminate and/or reduce effects is presented. A pathways analysis is then used to focus the assessment on key interactions between the NSDF Project and the environment by evaluating the different effect pathways to determine if, after incorporation of mitigation, there is still potential to cause residual effects. Where effects will be adequately mitigated and are not forwarded for further analysis (i.e., secondary pathways, or where mitigation will remove the pathway altogether), the reasons for concluding the assessment at this stage are articulated. Primary pathways that may lead to residual effects after incorporation of mitigation are further characterized in subsequent subsections of the assessment. As such, the “Project Interactions and Mitigation” section helps to focus the remainder of the assessment on those interactions (effects pathways) likely to result in residual adverse effects.

The first part of the analysis was to identify the potential effects pathways for all phases of the NSDF Project. The next step in the analysis was the development of environmental design features and mitigation that could be incorporated into the NSDF Project to eliminate and/or reduce adverse effects to surface water quality. Environmental design features included NSDF Project design elements, environmental best practices, and management policies and procedures. Environmental design features and mitigation were developed through an iterative process between the NSDF Project’s engineering and environmental teams, combined with input from Project-specific or regional engagement with other interested parties. The design features and/or mitigation were selected considering their effectiveness for implementation and maintenance, and their appropriateness within the context of the identified effect pathways.

After incorporation of mitigation, potential pathways were evaluated into the following categories using scientific knowledge, logic, experience with similar developments, and the effectiveness of environmental design features and mitigation:

- **No pathway –** pathway is removed by environmental design features or mitigation such that the NSDF Project would not be expected to result in a measurable environmental change relative to existing conditions, and therefore would have no residual effects to surface water quality.
- **Secondary pathway –** the pathway could result in a measurable minor environmental change, but would have a negligible residual effect on surface water quality relative to existing conditions and/or guideline values and is not expected to contribute cumulatively to other NSDF Project effects or to the effects of other past, present or reasonably foreseeable developments to cause a significant effect.
- **Primary pathway –** the pathway is likely to result in an environmental change relative to the existing conditions and/or guideline values that could contribute to residual effects to surface water quality.

Environmental design features and mitigation that have been or could be incorporated into the NSDF Project to eliminate and/or reduce adverse effects were considered. Potential pathways that were completely removed due to implementation of environmental design or mitigation were not assessed further. Pathways that were assessed to be secondary and demonstrated to have a negligible residual effect to surface water quality through simple qualitative or semi-quantitative evaluation of the pathway were also not advanced for further assessment. Primary pathways were carried forward for more detailed quantitative and qualitative effects analysis to characterize the residual effects of the NSDF Project.

5.4.2.6.2 Results

Pathways through which all stages of the NSDF Project may interact with and result in changes to measurement indicators for surface water quality are provided in Table 5.4.2-5.

Table 5.4.2-5: Pathways Analysis for the Surface Water Quality Valued Components

Project Activity	Effects Pathways	Management Practices and Mitigation Actions	Pathway Assessment
Project activities during the construction phase: ■ Site Preparation ■ Construction of the ECM ■ Blasting (as required) ■ Development of surface water management structures ■ Construction of the WWTP and other support facilities ■ On-site road and access development	Changes to local hydrology from surface disturbances may cause changes to water levels, flows, channel/bank stability, and sediment yield, at downstream locations, affecting water quality.	■ The NSDF Project footprint has been designed to avoid wetlands and limit disturbance to the natural environment to the extent feasible. For example, as the ECM is developed sequentially, undeveloped cells may be prepared and used as stockpile areas to store overburden soils to be used during construction or for daily/interim cover stockpiles. This approach reduces the required area for the laydown and stockpile of materials. ■ A 30 m buffer is established along all identified wetlands near the NSDF site. ■ Erosion and sediment control practices (e.g., silt fences, runoff management) applicable to the region and already in place at the CNL property will be used during construction around disturbed areas, where appropriate. ■ During the construction phase, erosion and sediment control measures in place to mitigate the effects of sediment transport include the use of erosion control blankets, as needed, to control erosion on steep slopes, check dams in ditches and swale. ■ Surface water from all external areas will be conveyed by ditches, swales and culverts to surface water management ponds to address water quality and water quantity criteria established for the wetland receiving waters and, ultimately, Perch Creek. ■ Where drainage crosses roadways, culverts are sized to convey the 25-year design event without road overtopping. ■ The surface water management ponds are designed to address erosion and sediment control concerns during construction by providing interim sediment control and by providing water quality/quantity controls during operations, closure, and post-closure. ■ Annual maintenance activities will identify any erosion problems. ■ A maintenance review will be completed after major storm events and after the annual springmelt to confirm there are no major erosion issues.	Secondary
	Surface water drainage through the Project site during construction of the engineered containment mound (ECM) may transport blasting residuals and metals directly into downstream waterbodies, affecting surface water quality.	■ A Blasting Plan will be developed and implemented for the NSDF Project. ■ Runoff from the Project site will be managed where appropriate (e.g., surface water management ponds) to avoid adverse environmental effects in downstream waterbodies. ■ Additional guidance for the NSDF Project blasting limits will be obtained from the Ontario Provincial Standard Specification (OPSS) in the document OPSS 120 – General Specification for Use of Explosives (OPSS 2008). ■ Blasting activities will follow industry standard Best Management Practices, applicable federal regulations, and Fisheries and Oceans Canada (DFO) guidelines for use of explosives. ■ Set-back distances required for blasting will be identified in the Blasting Plan. ■ Any runoff in contact with blasting residues at the NSDF Project site will be managed where appropriate (e.g., surface water management ponds) during the construction phase.	Secondary
■ Project activities during the construction phase (as listed above)	Discharge of domestic wastewater may cause a downstream change in surface water quality	■ The grey water/sewage will be stored in a holding tank at the NSDF Project site and periodically transferred to the CRL Sewage Treatment Plant.	No Linkage

Table 5.4.2-5: Pathways Analysis for the Surface Water Quality Valued Components

Project Activity	Effects Pathways	Management Practices and Mitigation Actions	Pathway Assessment
■ Project activities during the operation phase: ▪ Staged development of disposal cells in the ECM ▪ On-site transportation of waste and placement in the ECM ▪ Progressive closure of disposal cells and installation of cover ▪ Operation of the WWTP ▪ Existing presence of fencing around perimeter of ECM ▪ Surface water management ▪ Domestic waste (solid and liquid) management; and, ▪ Routine operational management and monitoring activities.	Air and dust emissions (including sulphur dioxide, nitrogen oxides, and particulate matter) and subsequent deposition may cause a change in surface water quality.	■ Implementation of CNL's Procedure for Management and Monitoring of Emissions, which includes operational control monitoring and verification monitoring. ■ The Dust Management Plan for the NSDF Project will be developed and will include: ▪ restricting or suspending activities if unacceptable amounts of dust are generated due to winds or other site conditions; ▪ use of water spraying or misting techniques (e.g., water trucks) as the primary dust control method; ▪ use of fixatives (e.g., chemical suppressant) for dust control during winter season or shutdown periods, and for use as daily/interim cover; ▪ suspension of excavating, loading, hauling, and dumping operations when wind speeds exceed the specified criterion; and ▪ vehicles that have come into contact with contamination will be required to pass through the vehicle decontamination facility. ■ On-site vehicles and equipment engines will meet Tier 2 emission standards and be maintained in good working order. ■ Limit idling of vehicles on-site.	Secondary
	Surface water runoff from the NSDF site can contain contaminants and suspended solids, which can affect water quality	■ Procedures for surface water management will be developed and implemented for the NSDF Project. ■ The target surface water quality objective is provided by MOECC in Stormwater Management Planning and Design Manual (MOECC 2003). ■ Surface water from all external areas will be conveyed by ditches, swales and culverts to surface water management ponds that will address water quality and water quantity criteria established for the wetland receiving waters and, ultimately, Perch Creek. ■ The surface water management ponds are designed to address erosion and sediment control concerns during construction by providing interim sediment control and by providing water quality/quantity controls during operations, closure, and post-closure. ■ The current surface water management pond footprints reflect the overall storage required to control post-closure flows to predevelopment levels for the 2-year through to 100-year rainfall events at the site. This volume also contains the storage required for sediment control during construction and water quality control during operations. ■ Where drainage crosses roadways, culverts are sized to convey the 25-year design event without road overtopping.	No Linkage
Project activities during the operations and closure phases: ■ Surface water management ■ Operation of the WWTP ■ Discharge of treated effluent from the WWTP	Discharge of treated effluent from the WWTP to the East Swamp Wetland may cause changes to water levels, flows, and channel/bank stability, and scouring of the wetland, affecting water quality at downstream locations.	■ Discharge of treated effluent to the exfiltration gallery area will help to reduce water loss from the hydrogeological system. ■ Outlet flows from all three surface water management ponds will be dispersed by level spreaders that will provide an even flow distribution to the wetland with an appropriately wide dispersal pattern. ■ The WWTP system's outlet utilizes a headwall which discharges to a level spreader for the purposes of preventing erosion and sedimentation at the outlet for the exfiltration gallery. ■ Current surface water management ponds outlet locations are limited by the site boundary (greater than 5 m separation required) so that there is no discharge from the spreader directly to the wetland. ■ Annual maintenance activities will identify any erosion problems. ■ A maintenance review will be completed after major storm events and after the annual spring melt to confirm there are no major erosion issues.	No Linkage
	Discharge of treated effluent from the WWTP to the East Swamp Wetland can cause changes to downstream surface water quality	■ The strategy for wastewater treatment is based on optimizing public and environmental protection by defining an approach to wastewater treatment that uses best demonstrated available technology that is economically achievable (BDATEA), and capable of meeting regulatory requirements. ■ The treatment target for effluent is the CRL Acceptability Criteria for Routine and Non Routine Discharge of Liquids to Stormwaters. ■ Treated effluent will be sampled and confirmed that it meets treatment targets before release to East Swamp Wetland ■ An exfiltration gallery is proposed at the discharge outlet to promote the exfiltration of treated water into the local groundwater regime. ■ Appropriate procedures to identify emergency spill occurrences and response, as well as appropriate response to non-contact surface water or leachate contamination will also be implemented as described in the Operations and Maintenance Plan and Contingency Plan	Primary

Table 5.4.2-5: Pathways Analysis for the Surface Water Quality Valued Components

Project Activity	Effects Pathways	Management Practices and Mitigation Actions	Pathway Assessment
	Leakage of leachate from the ECM during operations and closure may cause changes to downstream surface water quality.	■ Design of the ECM includes base contours that have been developed using a herringbone pattern with ridges and valleys to promote leachate transport to the leachate collection system for removal. ■ The base liner design include both primary and secondary liner systems that are designed to have redundancy in case of premature failure and are a combination of natural and synthetic barrier systems. ■ The HDPE geomembrane for the liner was selected as it is compatible with the leachate generated by the waste and will achieve a long service life. ■ The base liner system will include an underlying compacted clay liner to supplement the primary and secondary liner system. ■ The leachate collection system design will provide accessible access points for inspections, maintenance, repairs and replacements. ■ Sampling of the treated effluent will be completed in accordance with CNL's Management and Monitoring of Emissions Procedure.	No Linkage
Project activities during the closure and post-closure phases: ■ Installation of final ECM cover, restoration and grading of the site ■ On-going long-term performance monitoring, transfer of NSDF Project into Institutional Control	Installation of the final cover of the ECM and decommissioning of Project infrastructure may change downstream discharge, water levels, and channel/bank stability, affecting surface water quality	■ The final cover is designed to promote positive drainage from the NSDF Project site and reduce erosion or abrasion of the cover. ■ The final cover system will be constructed to promote the shedding of surface water to mitigate infiltration into the mound, and minimize leachate generation. ■ The cover system design incorporates a series of shallow, trapezoidal, riprap-lined drainage channels that are designed to convey water at low velocity. ■ The perimeter road ditch will route the runoff around the ECM perimeter to minimize ponding of water into the closed ECM, erosion of the cover and underlying waste materials, destabilization of the ECM structure, and damage to access roads. ■ The ECM final grading and drainage plan includes collection ditches along the top of the ECM berm road to collect side slope drainage. ■ Environmental monitoring will be completed throughout the post-closure phase for the NSDF Project to confirm that the cover is functioning as intended.	Secondary
Project activities during the closure and post-closure phases: ■ Installation of final ECM cover, restoration and grading of SSA ■ On-going long-term performance monitoring, transfer of NSDF Project into Institutional Control	Leakage of leachate from the ECM during the post-closure phase (i.e., after Year 2400) from liner and cover failure as a result of normal evolution can cause changes to downstream surface water quality.		Primary

This page intentionally left blank

5.4.2.6.2.1 No Linkage Pathways

Discharge of domestic wastewater may cause a downstream change in surface water quality

CNL's Sewage Treatment Plant receives approximately 700 m^3 of grey water/sewage per day from approximately 2,500 staff on the CNL property. An additional workforce of 50 staff will be required for the NSDF Project (see Section 3.12), generating grey water/sewage rates within those observed currently on the CRL property. The grey water/sewage from construction and operation of the NSDF Project will be stored in a holding tank at the NSDF Project site and periodically transferred to the Sewage Treatment Plant, which will have capacity to handle the additional grey water/sewage from the small increase in staff related to the Project.

There is no discharge of treated domestic sewage into Perch Lake or Perch Creek. As such, discharge of treated domestic wastewater for the NSDF Project to downstream locations is considered to be a no linkage pathway, and thus, a negligible residual effect on surface water quality.

Surface water runoff from the NSDF site can contain contaminants and suspended solids, which can affect water quality.

The surface water management ponds are designed to address erosion and sediment control concerns during construction by providing interim sediment control and by providing water quality/quantity controls during operations, closure, and post-closure. The current surface water management pond footprints reflect the overall storage required to control post-closure flows to predevelopment levels for the 2-year through to 100-year rainfall events at the site. This volume also contains the storage required for sediment control during construction and water quality control during operations. The target surface water quality objective is provided by the Ministry of Environment and Climate Change (MOECC) in Stormwater Management Planning and Design Manual (MOECC 2003), which reports a 60% total suspended solids (TSS) removal that provides a basic water quality treatment for discharge to the receiving wetland.

During the construction phase, erosion and sediment control measures will be in place to mitigate the effects of soil erosion and sediment transport. The measures include the use of erosion control blankets, as needed, to control erosion on steep slopes, check dams in ditches and swales, and the three proposed surface water management ponds that will be constructed to serve as interim sediment control facilities during construction, and then as stormwater management facilities during the operations, expansion and post-closure periods. Erosion and sediment control practices (e.g., silt fences, runoff management) applicable to the region and already in place at the CRL property (i.e., CNL's Management of Land and Habitat Procedure) will be used around disturbed areas, where appropriate.

Site operations include surface water management for the ECM and all external areas. Surface water from all external areas will be conveyed by ditches, swales and culverts to surface water management ponds that will address water quality and water quantity criteria established for the wetland receiving waters and, ultimately, Perch Creek. Contact surface water drainage from the active cells of the ECM will be to the WWTP. Non-contact surface water drainage from completed cells and yet-to-be-activated cells will be directed either by gravity to the external surface water management system or to temporary holding ponds within the ECM, or then pumped to the three surface water management ponds. There will be a need to address pre-treatment of surface water run-off from the active cells prior to conveyance to the WWTP and a need to establish conveyance mechanisms (gravity and pumping) from the interior of the ECM to the surface water management ponds.

Facility inspections will be completed twice annually to confirm that inlets and outlets are clear of debris and to confirm that there are no major erosion issues at the inlet or outlet. As well, the integrity of berms and outlet structures will be confirmed by visual inspections (e.g., to identify any animal burrowing activity or active soil erosion). Inspections will also include an annual sediment level monitoring component within each pond to identify sediment accumulation rates that may require clean-out requirements. If necessary, pond sediment will be extracted by excavation equipment and will be disposed of based on sediment sampling, testing, and classification according to MOECC standards, or stockpiled, de-watered and re-used on-site for ECM cover operations. Sediment removal will follow procedures identified in the Stormwater Management Planning and Design Manual (MOECC 2003).

Roadway, sidewalk, and parking lot winter maintenance activities that may release road salt to the environment, include snow plowing/shoveling and de-icing practices, salt and sand storage and snow stockpiling, removal, and disposal. The current winter maintenance practices outlined in the CRL Salt Management Plan provide for effective management of salt use, and will be applied to the NSDF Project, as necessary. As per the plan, the application of road salt on the NSDF site will be to be limited as salt residual within contact water and/or leachate may compromise the treatment effectiveness of the WWTP systems. Instead, alternative products in winter road management, such as a sand-stone mixtures, are currently being considered.

The implementation of these surface water runoff mitigation strategies will reduce the potential for changes to soil, water and vegetation quality from surface water runoff from the NSDF site. This pathway was determined to have no linkage to effects to water quality.

Discharge of treated effluent from the WWTP to the East Swamp Wetland may cause changes to water levels, flows, and channel/bank stability, affecting water quality at downstream locations.

The major flow system for all three surface water management ponds will discharge to the adjacent wetland and will be dispersed by level spreaders that will provide an even flow distribution to the wetland with an appropriately wide dispersal pattern. The WWTP outlet uses a headwall that discharges to a level spreader for the purposes of preventing erosion and sedimentation at the outlet. An exfiltration gallery is proposed at the discharge outlet to promote the exfiltration of treated water into the local groundwater regime. The proposed surface water management ponds outlet locations are limited by the site boundary (greater than 5 m separation required) so that there will be no discharge from the spreader directly to the wetland. Local topography between the level spreader and the wetland, as well as any setbacks, has influenced the location of the level spreader on site.

Annual maintenance activities will identify erosion issues. Facility inspections will be completed twice annually to confirm that inlets and outlets are clear of debris and to confirm that there are no major erosion issues at the inlet or outlet. In addition, a maintenance review will be completed after major storm events and after the annual spring melt to confirm there are no major erosion issues at the dispersion outlets. As a result of the design of the surface water management pond outlets, and the proposed low discharge rates (i.e., 1 m^3/hr), the discharge of treated effluent from the WWTP to the East Swamp Wetland is not predicted to result in changes to water levels, flows, and channel/bank stability, that would affect water quality at downstream locations. As a result, this pathway was determined to have no linkage to effects to water quality.

Leakage of leachate from the ECM during operations and closure may cause changes to downstream surface water quality.

Design of the ECM includes base contours that have been developed using a herringbone pattern with ridges and valleys to promote leachate transport to the leachate collection system for removal. The base liner design includes both primary and secondary liner systems that are designed provide redundancy in case of premature failure and are a combination of natural and synthetic barrier systems. The primary liner includes a leachate collection system with the secondary liner housing a leak detection system. The composite base liner contains perforated high-density polyethylene (HDPE) collection and pipes. The HDPE geomembrane was selected as it is compatible with the leachate generated by the waste and is expected to perform as an effective hydraulic and diffusion barrier over the 500-year design life (see Section 3.5.2.4). The base liner system includes an underlying compacted clay liner to supplement the primary and secondary liner system. The leachate collection system design provides access points for inspections, maintenance, repairs and replacements.

The primary liner system will contain the leachate collection system, and will convey leachate to a single collection point for removal from the mound, for transfer to the WWTP for treatment. The primary liner system serves as the primary source of protection for the natural environment below the mound from leachate migration. The secondary liner system will contain the leak detection system, which will be used to detect leaks in the unlikely event that the primary liner system fails. Leachate collected by the leachate collection system will be pumped to the onsite WWTP for treatment.

Designed berms consist of three main geotechnical elements, or layers, each contributing to the soundness and integrity of the berm itself and the whole ECM. A Slope Stability Analysis was completed to provide the information needed to support the design of the base slopes, sidewalls, and side slopes of the ECM. The Slope Stability Analysis addresses the range of anticipated loading conditions, under both short-term and long-term scenarios, to confirm that the slope designs will satisfy minimum factor-of-safety requirements for stability. Size and shape of the berms and each of the elements and layers were determined using a seismic design basis, including the National Building Code of Canada (NBCCC).

The implementation of the above mitigation will limit the potential for changes to groundwater and surface water quality from the NSDF site. As such, this pathway is determined to have no linkage to surface water quality.

5.4.2.6.2.2 Secondary Pathways

The following pathways were assessed as potentially having a measurable minor environmental change, but resulting in a negligible residual effect to surface water quality relative to the Base Case.

Changes to local hydrology from surface disturbances may affect downstream water levels, flows, channel/bank stability, and sediment yield, affecting surface water quality.

The installation of the final cover of the ECM and decommissioning of Project infrastructure may change downstream discharge, water levels, and channel/bank stability, affecting surface water quality.

Changes to surface flows, water levels, and water quality from NSDF Project construction and decommissioning are expected to be limited using environmental design features and mitigation. The NSDF Project footprint was designed to be as small as possible to limit disturbance to the natural environment to the extent feasible and will avoid stream and wetland habitats. For example, as the ECM is developed sequentially, undeveloped cells may be prepared and used as stockpile areas to store overburden soils to be used during construction or for

daily/interim cover stockpiles. This approach reduces the required area for the laydown and stockpile of materials. In addition, a 30 m buffer is established along all identified wetlands near the NSDF site.

All proposed physical works are located within the SSA, affecting a relative small area (4.1%) of the total contributing basin area for Perch Creek (720 ha; Robertson and Barry 1985). Any changes to existing drainage patterns will largely be restricted to this small sub-basin. The total annual volume of contact surface water to be treated is 6,556 m^3. The volume represents approximately 0.38% of the average total outflow from Perch Lake (1,700,000 cubic metres per year (m^3/yr)), or 0.30% of the average total outflow from Perch Creek (2,200,000 m^3/yr). Operational treated effluent discharge is expected to be less than 1 cubic metres per hour (m^3/hr). Flow rates within Perch Creek are approximately 252 m^3/hr; the effluent discharge rate is roughly 0.4% of the average Perch Creek flows and approximately 11.5% of East Swamp Weir flows. Furthermore, the receiving wetlands are expected to buffer the discharge, further reducing flow rates into Perch Creek.

All non-contact and contact surface water will be managed within the NSDF Project site, as per the Surface Water Management Plan that will be developed, reducing the potential for the NSDF Project to affect downstream discharge, water levels, and channel/bank stability. Erosion and sediment control practices (e.g., silt fences, runoff management) applicable to the region and already in place at the CNL property will be used during construction and decommissioning around disturbed areas, where appropriate.

Closure activities include the installation of an engineered cover over the ECM to limit ponding and water infiltration in to the waste. Modification to the drainage ditches and conveyance channels will be made to promote positive drainage from the site and limit erosion or abrasion of the cover. Run-off control for the cover is designed to limit ponding and infiltration of water into the ECM, erosion of the cover and waste material, and destabilization of the structure. The ECM design approach is to control the direction and velocity of the run-off to prevent erosion and abrasion of the cover. Any surface water infiltrating the final cover will be collected by the leachate collection system and sent to the WWTP. The three surface water management ponds will remain to promote infiltration and settlement of suspended solids and restrict discharge rates to the nearby wetland. Decommissioning of the WWTP and all associated surface water management structures will be completed after the leachate quantity and quality no longer requires treatment. In addition, environmental monitoring will be completed throughout the post-closure phase for the NSDF Project to confirm that the cover is functioning as intended.

Mitigation associated with the implementation of the Surface Water Management Plan for the NSDF Project to manage hydrological changes through surface disturbance during operations and closure is expected to limit potential changes to downstream discharge, water levels, and channel/bank stability in Perch Creek. As such, negligible residual effects are predicted to surface water quality in the receiving and downstream environment.

Surface water drainage through the Project site during construction of the ECM may transport blasting residuals and metals directly into downstream waterbodies, affecting surface water quality

Use of ammonium nitrate/fuel oil (ANFO) and water resistant bulk emulsion explosives during the construction of the ECM has the potential to affect surface water quality in the Perch Creek Basin through runoff coming into contact with residual nitrogen material (e.g., nitrate and ammonia) in the construction area. A detailed Blasting Plan will be developed and implemented for the NSDF Project, which will comply with DFO Guidelines for the Use of Explosives in or Near Canadian Fisheries Waters (Wright and Hopky 1998) and DFO's *Measures to Avoid Causing Harm to Fish and Fish Habitat including Aquatic Species at Risk* (DFO 2016). Additional guidance will be

obtained from the Ontario Provincial Standard Specification (OPSS) in the document OPSS 120 – General Specification for Use of Explosives (OPSS 2008).

Set-back distances required for blasting will be identified in the Blasting Plan. Any runoff in contact with blasting residues at the NSDF Project site will be managed according to the Surface Water Management Plan (e.g., directed to surface water management ponds and associated systems) during the construction phase. In addition, the potential for transporting blasting residuals into downstream waterbodies is minimized as blasting operations are limited to a relatively short period of time during the construction phase.

Consequently, the use of explosives for the development of the ECM in the proposed NSDF Project is considered to potentially influence runoff quality with respect to minor increases in nitrate and ammonia concentrations for a short period in the construction phase. As such, negligible residual effects are predicted to surface water quality in the receiving and downstream environment.

Non-radiological air emissions and dust emissions (including sulphur dioxide, nitrogen oxides [NOx/NO_2], and particulate matter) and subsequent deposition may cause a change in surface water and sediment quality.

Construction and operation of the NSDF Project will generate air and dust emissions such as carbon monoxide (CO), oxides of sulphur (SO_x includes sulphur dioxide [SO_2]), oxides of nitrogen (NO_x includes nitrogen dioxide NO_2), particulate matter ($PM_{2.5}$, PM_{10}), and suspended particulate matter (SPM). Air emissions, such as SO_x and NO_x, can result from the use of fossil fuels in generators, vehicles, and machinery. Vehicle exhaust and fugitive dust from unpaved and paved roads is the largest contributor to particulate matter (SPM, PM_{10}, and $PM_{2.5}$) during both construction and operations phases (Section 5.2.1.6.2).

Examples of mitigation implemented to limit predicted residual effects from NSDF Project emissions to air quality (and subsequently surface water quality) include:

- implementation of CNL's Procedure for Management and Monitoring of Emissions, which includes operational control monitoring and verification monitoring;
- development and implementation of the Dust Management Plan for the NSDF Project;
- the primary dust control method will include water spraying or misting techniques (e.g., water trucks);
- on-site vehicles and equipment engines will meet Tier 2 emission standards and be maintained in good working order; and,
- limiting idling of vehicles on-site.

Dust control will be conducted to support waste placement operations in accordance with the Dust Management Plan during loading, transportation, placement and compaction operations. Work areas that have the potential for generating dust will require implementation of dust suppression technique. The primary dust control method will include water spraying or misting techniques (e.g., water trucks). Water application is controlled to avoid generation of free liquids. Fixatives (e.g., chemical suppressant) may also be used for dust control during winter season or shutdown periods, and for use as daily/interim cover. The use of fixatives is reviewed prior to application for potential effects on leachate and surface water runoff generated by the ECM.

Vehicle exhaust and fugitive dust from unpaved roads is the largest contributor to particulate matter (SPM, PM_{10}, and $PM_{2.5}$) during both the construction and operations phases. Vehicle exhaust during the construction of the ECM is the largest contributor of NO_x/NO_2 and CO. Predicted concentrations for the Application Case during both construction and operations phases are below applicable air quality guidelines and/or standards (Section 5.2.1.6.2, Table 5.2.1-14). With the implementation of CNL's Management and Monitoring of Emissions Procedure, and through the implementation of the Dust Management Plan for the NSDF Project, air and dust emissions and subsequent deposition are expected to result in local, minor changes to surface water quality relative to Base Case conditions. As such, this pathway is determined to result in a negligible residual effect on surface water quality.

5.4.2.6.2.3 Primary Pathways

The following primary pathways were identified as having the potential to result in residual effects to surface water quality, and therefore, have been carried forward to the residual effects analysis.

- Discharge of treated effluent from the WWTP to the East Swamp Wetland can cause changes to downstream surface water quality.
- Leakage of leachate from the ECM during the post-closure phase (i.e., after Year 2400) from liner and cover failure as a result of normal evolution can cause changes to downstream surface water quality.

5.4.2.7 Residual Effects Analysis

Residual effects to surface water quality are limited to the primary pathway of operational discharges from the WWTP and leakage of leachate from the ECM during the post-closure phase, and their potential to change surface water chemistry in the receiving and downstream environment. This assessment is limited to non-radiological constituents.

5.4.2.7.1 Methods

5.4.2.7.1.1 Model Overview

GoldSim is a graphical Windows-based simulation software developed by GoldSim Technology Group. It is used to dynamically model complex systems to support decision making and is often applied to environmental, mining, and water resource systems. GoldSim has a general purpose and flexible modelling framework that can be applied by multiple disciplines. It uses a high-level programming language in a visual and hierarchical modelling environment, which allows user to construct models by adding elements that represent data, equations, processes, or events, and linking them together. The result is a graphical representation, similar to a simple flow diagram; where links and formula influences are clearly visible. The GoldSim modelling package was employed as a "graphical spreadsheet" to estimate non-radioactive contaminant concentrations at focal surface water features within the Perch Creek Basin catchment based on a mass balance approach. The model was run using site specific information, and projected flow data and projected wastewater effluent quality and quantity data for select parameters of potential concern provided by previous hydrologic studies, recent water quality reports, and the Project Description.

The following list summarizes the water quantity and quality reference documents used to characterize the existing (Base Case) and projected Assessment Scenarios in the surface water quality GoldSim model:

- Water Quantity:
  - Average monthly flow rates and precipitation data from 1969 to 1980 for fives Perch Lake inlets (PL1, PL2, PL3, PL4, and PL5) and one outlet flow (PL0; Robertson and Barry 1985).
  - Monthly flow rates based on an annual averages for Main Stream Culvert (MSC), South Swamp Weir (SSW), and East Swamp Weir (ESW) (CNL 2016b).
  - Projected leachate generation rates from the November 2016 AECOM 60% Design Deliverable for Leachate and Wastewater Characterization.
  - Perch Creek catchment annual flow rates downstream of Perch Lake Outlet (PL0) (CNL 2016b, CW-511300-PRO-647).
- Water Quality:
  - Average annual non-radioactive water chemistry background concentrations at surface water model nodes of interest from 2010 to 2015 (CNL 2016a).
  - Non-radioactive surface water quality benchmarks (CNL 2016a).
  - Projected untreated leachate concentrations have been established based on pilot wastewater treatment studies.
  - Projected removal efficiencies and untreated leachate concentrations have been established based on pilot wastewater treatment studies.
  - Water quality benchmarks based on the Canadian Water Quality Guidelines (CWQG), a previous Environmental Risk Assessment (ERA; CRL 2013), and a previous EER (EcoMetrix Inc. 2005).

5.4.2.7.1.2 Model Scenarios

The model was run for four separate scenarios designed to simulate operational phases, post-closure, and post-institutional control period for the ECM. The ECM will have a final waste capacity of 1,000,000 m^3 and will be comprised of ten cells – each with an average surface area of approximately 12,000 m^2. The construction phase from 2018 to 2020 was removed from consideration as a model scenario because of its short time period (because parameters of potential concern were not expected to be generated in substantial volumes during construction to affect receiving and downstream water quality as described in Section 5.4.2.6.2.1).

Scenario 1

- This scenario simulates the first operational phase from 2020 to 2025 immediately after the construction phase (2018 to 2020). In this scenario, the ECM is defined as one single active cell which discharges leachate effluent to an infiltration area after treatment at the WWTP. The infiltration area is considered to be the downstream portion of East Swamp (upstream of East Swamp Weir).
- Treated wastewater discharges to East Swamp at an annual average flow rate of 4,656 m^3/yr.

Scenario 2

- This scenario simulates the operational phase from 2065 to 2070 where the ECM is operating with multiple active and closed cells (six closed, three interim cells, and one active cell) with the cover intact.
- Treated wastewater discharges to East Swamp at an annual average flow rate of 6,456 m^3/yr.

Scenario 3

- This scenario simulates the post-closure phase after 2100 where all ten cells of the ECM are closed with the cover intact, and the WWTP decommissioned.
- Untreated leachate discharges to East Swamp at an annual average flow rate of 110 m^3/yr.

Scenario 4

- This scenario simulates a post-institutional control phase beyond the year 2400 where a bathtub effect occurs with spill-over occurring along the southern border of the ECM due to the degradation and inevitable failure of the cover. Spill-over at the southern border of the ECM results in the shortest flow path and residence time towards Perch Creek instead of flowing into East Swamp.
- Upon cover failure, untreated leachate discharges into Perch Creek along its northern stream bank (between Perch Lake and Perch Creek Weir approximately 1.5 km from Ottawa River) at a daily average flow rate of 120 m^3/d (43,200 m^3/yr). The total waste volume will require approximately 25 years to fully discharge into Perch Creek.

In summary, Scenarios 1 and 2 were modelled to accommodate for the various potential operating configurations for the ECM depending on the volume of waste to be managed. Scenario 3 was modelled to determine the effects of untreated leachate on the receiving environment during post-closure. Scenario 4 was modelled in anticipation of the inevitable failure of the ECM cover at the end of its design life (approximately 500 years) – recognizing that wastewater treatment methods that are referred to in this study are not intended to address this failure scenario. Scenario 4 was modelled as a conservative “worst-case” scenario to gain a better understanding of the assimilative capacity of the Perch Creek watershed.

Specific wastewater treatment methods, including removal efficiencies, have been established based on pilot wastewater treatment studies. This water quality modeling exercise was conducted to continued guidance in determining best-practice wastewater treatment methods to address potential benchmark non-compliances associated with the parameters of potential concern.

5.4.2.7.1.3 Model Inputs and Assumptions

GoldSim was run for all four scenarios using monthly time steps for a total of 178 months, or approximately 15 years, to illustrate long-term concentration trends. The mass balance calculations assumed year-to-year continuous effluent discharge, instantaneous and complete mixing, and contaminants were modelled to be fully conservative (no decay and no sorption). Perch Lake was simulated as a reservoir storage unit with multiple inflow sources (P1, P2, P3, P4, and P5) and one outflow location (PL0), with an initial volume of approximately 900,000 m^3.

The model considered several nodes upstream of Perch Lake, namely, Main Stream Culvert (MSC), South Swamp Weir (SSW), and East Swamp Weir (ESW), which correspond to the surface water quality monitoring stations as

shown in Figure 5.4.1-1. Similarly, downstream nodes relative to Perch Lake include Perch Creek Weir (PCW) and Perch Creek Outlet (PCO) where PCO is assumed to be fully mixed at the confluence with Ottawa River.

Measured monthly flows were solely available at PCW from 2001 to 2015 – the rest of the model flows were based on a previous water balance study (Barry 1985). Nonetheless, GoldSim was run during the period of 2001 to 2015 using a looping series of average monthly flows with the expectation that, should more detailed measured flow data become available in the future, new flow data may be readily input in the model.

The water balance study provided monthly estimates of inflow and outflow at the Perch Lake inlets and outlets with an average annual surplus of approximately 52,000 m^3 – this discrepancy interferes with the assumption that the lake volume will remain constant in the model since the surplus represents a non-trivial 6% of the lake's total volume. In order to maintain a constant volume within Perch Lake and to reduce model complexity, the annual surplus was nullified by considering an equal outflow amount as potential evapotranspiration. Monthly seasonal variation was achieved by examining Environment Canada water balance evapotranspiration trends from years 1970 to 2006 at the AECL 6101335 meteorological station. Due to the limited resolution of the input data and the lack of measured data, year-to-year (wet year or dry year) seasonal variation was not considered in the water quality model.

Model inflow rates for Perch Lake inflows were assumed to be representative of a typical year with high snowmelt flows occurring in April. In the interest of using consistent input data, measured monthly flow data at Perch Creek Weir were not used in conjunction with the rest of the model, which relied predominantly upon monthly and annual averages.

The water balance from the study by Barry conducted in 1985 estimated an annual average flow rate at the outlet of Perch Lake of approximately 1,788,000 m^3/yr – a reasonable estimate in comparison to the annual average flow rate at the same outlet of 1,700,000 m^3/yr provided by CNL. The identical study by CNL provided an estimate of the average annual flow rate at the outlet of Perch Creek of 2,210,000 m^3/yr.

5.4.2.7.1.4 Model Screening for Constituents of Potential Concern

Preliminary screening for constituents of potential concern (COPCs) to be included in the model was based on the following factors:

1) Parameter Type: Trace organic compounds were eliminated from further analysis as this model assumes no decay mechanisms; the complexities for organic decay and bioaccumulation are beyond the scope of the water quality model.

2) Toxicity: metals forwarded for further consideration as COPCs are those known to be chronically or acutely toxic to aquatic life (i.e., Arsenic, Cadmium, Chromium, Copper, Lead, Mercury, and Nickel).

3) Projected Effluent Concentration: Other toxic metals and elements (i.e., Beryllium, Cobalt, Fluorine, and Thallium) were omitted from the study due to the lack of projected effluent concentrations.

4) Untreated Effluent Concentration:

   - Despite their substantially lower effluent concentrations relative to their respective BV, a few parameters were also forwarded for further analysis (i.e., Nitrate and Phosphorus) due to their role in contributing to the trophic state of water bodies.

- Remaining non-toxic and non-nutrient parameters (i.e., Iron and Zinc) were included as COPCs due to their abnormally high (at least one order of magnitude higher) discharge concentrations relative to their respective BV.

Preliminary screening removed the following cations from further analysis: Boron, Calcium, Potassium, Sodium, and Strontium. Similarly, based on the screening process, a number of anions were not considered to be COPCs: Chloride, Fluoride, Sulfate, and Bicarbonate Alkalinity. The final list of COPCs and their projected untreated effluent characteristics are summarized in Table 5.4.2-6, including their respective effluent treatment targets and BVs.

Table 5.4.2-6: Screening of Constituents of Potential Concern

Parameter	Units	Projected Untreated Effluent Characteristics[(a)]	Treatment Target[(a)]	Benchmark Values[(b)]
			AECOM 60% Design Deliverable 1.16	CRL 2015 ASR Table 6.2
Arsenic	µg/L	3.6	50	48
Aluminum	µg/L	150	50	460
Barium	µg/L	1,800	4	n/a
Cadmium	µg/L	3	100	0.15
Chromium	µg/L	5	20	44
Copper	µg/L	100	20	2
Iron	mg/L	125	1	0.3
Lead	µg/L	20	20	18.8
Manganese	µg/L	5,800	120	n/a
Mercury	µg/L	1.8	n/a	0.23
Nitrate	mg/L	n/a	13	n/a
Phosphorus[(c)]	mg/L	4	5	4 – 100
Zinc	µg/L	200	300	30

µg/L = micrograms per litre; mg/L = milligrams per litre; n/a = not available

shading = parameter in exceedance of its BV (based on the more stringent BV) and the associated projected untreated effluent characteristic.

(a) From Table 4 of AECOM 60% Design Deliverable 1.16 (AECOM 2016b), except Mercury. Mercury characteristics were obtained from (232-503230-021-000, 8106-MG-2016-16, October 2016).

(b) From Table 6-2 of CRL-509243-ASR-2015 where benchmarks are based upon CWQG (Canadian Water Quality Guidelines), EER (Ecological Effects Review), ERA (Ecological Risk Assessment)

(c) Projected effluent concentration was provided as Phosphate (4 mg/L) according to the AECOM 60% Design Deliverable 1.16 (AECOM 2016b) with a target treatment concentration of 5 mg/L (as Phosphorus). Benchmark values from CRL 2015 ASR Table 6.2 present a range from 4 – 100 mg/L depending on the trophic state of the lake (ultra-oligotrophic <4, oligotrophic 4-10, mesotrophic 10-20, meso-eutrophic 20 -35, eutrophic 35-100, and hyper eutrophic >100 mg/L as P).

Table 5.4.2-6 provides the final list of COPCs where cells highlighted in gray indicate an exceedance of the effluent limit or BV and the associated projected untreated effluent concentration. Effluent limits are applied at the point of discharge (WWTP outfall location). It is noteworthy to point out that between the design treatment targets and the BVs from the CRL 2015 ASR, the more stringent (i.e., the lower value) was selected for further analysis and discussion of model results. With the exception of Phosphorus, Nitrate, and Mercury, all other BVs were based on the 2012 ERA conducted by CNL (2013). Phosphorus and Nitrate BVs were referenced from CWQG, whereas the BV for Mercury was specified in the 2005 Ecological Effects Review (EER; EcoMetrix 2005).

Background concentrations of these select water quality parameters from Perch Creek Weir were omitted from the model as the summation of upstream background concentrations were found to be more representative of the background concentration at that particular node, especially due to the data gaps found in the time series data at Perch Creek Weir.

No measured background concentration information was available for Perch Lake itself, and thus the lake was assigned an assumed initial concentration equivalent to the sum of PL1, PL2, PL3, PL4, and PL5, 15-year average concentrations.

This surface water primary pathway assessment was conducted with conservative estimates of concentration by using untreated leachate concentrations originating from the WWTP for post-closure Scenario 3 and post-institutional control Scenario 4. Untreated leachate concentrations are based on the bounding estimate of radionuclide inventory in the ECM. This represents a bounding estimate of the ECM inventory for the total waste volume of the completed ECM (1,000,000 m^3) used for assessment purposes. The inventory is a reference inventory based on the existing characterized waste streams, which form a small portion of the inventory. This was extrapolated to 1,000,000 m^3 using expert opinion. While there is uncertainty with this data set, the waste quality and characterization program will assure the inventory envelope is not exceeded. The reference inventory is considered to be a conservative; thus, treated leachate concentrations are expected to be considerably lower. These lower treated effluent concentrations were used for Scenarios 1 and 2, when the WWTP is expected to be fully operational. Percent removal efficiencies for each COPC are presented in Table 5.4.2-7 and have been established based on pilot wastewater treatment studies.

Table 5.4.2-7: WWTP Removal Efficiencies for Constituent of Potential Concern

Parameter	Units	Treatment Target	Removal Efficiency	Untreated Effluent	Treated Effluent
Arsenic	µg/L	48	n/a	3.6	3.6
Aluminum	µg/L	50	96.5%	150	5.25
Barium	µg/L	4	97.0%	1,800	54
Cadmium	µg/L	0.15	90.9%	3	0.273
Chromium	µg/L	20	99.1%	5	0.045
Copper	µg/L	2	98.0%	100	2
Iron	mg/L	0.3	100.0%	125	0
Lead	µg/L	18.8	95.0%	20	1
Manganese	µg/L	120	99.0%	5,800	58
Mercury	µg/L	0.23	n/a	1.8	1.8
Nitrate	mg/L	13	n/a	n/a	n/a
Phosphorus	mg/L	35	56.6%	4	1.736
Zinc	µg/L	30	93.2%	200	13.6

Shading = exceedance of treatment target.

Table 5.4.2-7 shows that the WWTP is able to remove high concentrations of a majority of COPCs; however, Barium and Cadmium are expected to persist at concentrations above the treatment target despite treatment. The removal efficiency for Mercury was not available; thus, the treated effluent was assumed to the identical to untreated effluent for this parameter in order to be conservative.

5.4.2.7.2 Application Case Results

Detailed GoldSim surface water quality modelling results are presented in the following section.

5.4.2.7.2.1 Model Results for Parameters of Potential Concern

The nodes at which water quality concentrations were estimated are listed as follows:

1) ESW: East Swamp Weir;
2) PL2: Perch Lake Inlet 2;
3) PL: Perch Lake;
4) PCW: Perch Creek Weir; and
5) PCO: Perch Creek Outlet.

Model results for the parameters of potential concern are presented by node and model scenario for the average annual concentration, including the annual median, annual 95th percentiles of the monthly maximum, and monthly maximum. All concentrations are inclusive of the background concentrations (at nodes were background information was available). Cells highlighted in grey indicate an exceedance in comparison to the treatment target or BV (whichever is more stringent)

For all COPCs, where removal efficiencies were available, treated effluent was used to model Scenarios 1 and 2, whereas untreated effluent was used to model Scenarios 3 and 4.

Cadmium

The background concentration of Cadmium in the Perch Creek watershed ranged between 0.015 to 0.126 µg/L, (Table 5.4.2-8). In all scenarios, mean concentrations at all assessment nodes in the Perch Lake watershed remain below the BV of 0.15 µg/L (Table 5.4.2-8). This is also the case for the upper bound projections (i.e., the 95th percentile and maximum modelled concentrations, with the exception of Scenarios 1 and 2 at ESW, and Scenario 4 at PCW.

Table 5.4.2-8: Water Quality Modeling Results for Cadmium

Cadmium	Units	ESW	PL2	PL	PCW	PCO
Benchmark Value	µg/L	0.15				
Background Concentration (i.e., Base Case)	µg/L	0.107	0.051	0.126	0.015	n/a
Mean	µg/L	0.129	0.053	0.036	0.027	0.025
Median	µg/L	0.124	0.052	0.036	0.028	0.025
95th Percentile	µg/L	0.153	0.056	0.038	0.035	0.033
Maximum	µg/L	0.153	0.056	0.038	0.035	0.033
Mean	µg/L	0.135	0.054	0.036	0.028	0.025
Median	µg/L	0.129	0.053	0.036	0.028	0.025
95th Percentile	µg/L	0.165	0.057	0.038	0.035	0.033
Maximum	µg/L	0.165	0.057	0.038	0.035	0.033
Mean	µg/L	0.119	0.051	0.035	0.027	0.024
Median	µg/L	0.115	0.051	0.035	0.027	0.024
95th Percentile	µg/L	0.135	0.052	0.038	0.034	0.033
Maximum	µg/L	0.135	0.052	0.038	0.034	0.033
Mean	µg/L	0.107	0.051	0.034	0.105	0.093
Median	µg/L	0.107	0.051	0.034	0.105	0.094
95th Percentile	µg/L	0.107	0.051	0.037	0.164	0.135
Maximum	µg/L	0.107	0.051	0.037	0.166	0.136

Shading = exceedance of treatment target.

Copper

The background concentration of Copper in the Perch Creek watershed ranged between 4.8 to 13.9 µg/L for all assessment nodes. This concentration range is well above the BV for Copper of 2 µg/L (Table 5.4.2-9). In all scenarios for all assessment nodes in the Perch Lake watershed, projected data are above the BV, but remain within the background data range (Table 5.4.2-9). The incremental increase in Copper as a result of the Project is indiscernible.

Table 5.4.2-9: Water Quality Modeling Results for Copper

Copper	Units	ESW	PL2	PL	PCW	PCO
Benchmark Value	µg/L	2.0				
Background Concentration	µg/L	5.1	8.6	13.9	4.8	n/a
Mean	µg/L	4.65	8.49	5.21	4.03	3.62
Median	µg/L	4.74	8.51	5.29	4.01	3.66
95th Percentile	µg/L	4.99	8.54	5.64	5.10	4.90
Maximum	µg/L	4.99	8.54	5.64	5.10	4.90
Mean	µg/L	4.53	8.46	5.21	4.03	3.62
Median	µg/L	4.64	8.49	5.29	4.01	3.65
95th Percentile	µg/L	4.97	8.54	5.63	5.09	4.89
Maximum	µg/L	4.97	8.54	5.64	5.10	4.90
Mean	µg/L	5.44	8.57	5.23	4.04	3.63
Median	µg/L	5.33	8.57	5.31	4.01	3.66
95th Percentile	µg/L	5.98	8.60	5.65	5.10	4.90
Maximum	µg/L	5.98	8.60	5.65	5.11	4.91
Mean	µg/L	5.05	8.55	5.11	6.60	5.88
Median	µg/L	5.05	8.55	5.18	6.66	5.98
95th Percentile	µg/L	5.05	8.55	5.57	7.94	6.53
Maximum	µg/L	5.05	8.55	5.58	7.98	6.55

Shading = exceedance of treatment target

Iron

The background concentration of Iron in the Perch Creek watershed ranged between 2.3 to 4.8 mg/L (Table 5.4.2-10). This concentration range is well above the BV for Iron of 2 µg/L. In all scenarios at all assessment nodes in the Perch Lake watershed, projected data are above the BV, but remain within the background data range (Table 5.4.2-10). The incremental increase in Iron as a result of the Project is generally non-indiscernible, but for PL2, PL and PCW Iron concentrations decrease, most likely as a result of dilution. The exception is higher upper bound projections compared to the background concentrations (i.e., the 95th percentile and maximum modelled concentrations) for Scenario 4 at PCW and PCO.

Table 5.4.2-10: Water Quality Modeling Results for Iron

Iron	Units	ESW	PL2	PL	PCW	PCO
Benchmark Value	mg/L	0.3				
Background Concentration	mg/L	2.3	2.5	3.9	4.8	n/a
Mean	mg/L	2.01	2.48	1.48	1.15	1.03
Median	mg/L	2.08	2.49	1.51	1.14	1.04
95th Percentile	mg/L	2.27	2.50	1.60	1.45	1.39
Maximum	mg/L	2.27	2.50	1.60	1.45	1.39
Mean	mg/L	1.92	2.47	1.48	1.15	1.03
Median	mg/L	2.00	2.48	1.50	1.14	1.04
95th Percentile	mg/L	2.26	2.50	1.60	1.45	1.39
Maximum	mg/L	2.26	2.50	1.60	1.45	1.39
Mean	mg/L	2.82	2.53	1.49	1.15	1.04
Median	mg/L	2.67	2.52	1.52	1.14	1.05
95th Percentile	mg/L	3.52	2.57	1.61	1.46	1.40
Maximum	mg/L	3.52	2.57	1.61	1.46	1.40
Mean	mg/L	2.32	2.50	1.46	4.40	3.89
Median	mg/L	2.32	2.50	1.48	4.42	3.96
95th Percentile	mg/L	2.32	2.50	1.59	6.85	5.64
Maximum	mg/L	2.32	2.50	1.59	6.93	5.69

Shading = exceedance of treatment target

Lead

The background concentration of Lead in the Perch Creek watershed at all assessment nodes ranged between 0.0 to 0.7 µg/L, well below the BV for Lead of 18.8 µg/L (Table 5.4.2-11). In all scenarios at all assessment nodes in the Perch Lake watershed, projected data remained within compliance with the BV (Table 5.4.2-11). Slight incremental changes were evident at all assessment nodes, with the exception of slightly higher upper bound projections compared to the background concentrations (i.e., the 95th percentile and maximum modelled concentrations) for Scenario 4 at PCW and PCO.

Table 5.4.2-11: Water Quality Modeling Results for Lead

Lead	Units	ESW	PL2	PL	PCW	PCO
Background Value	µg/L	18.8				
Background Concentration	µg/L	0.4	0.7	1.7	0.0	n/a
Mean	µg/L	0.49	0.65	0.46	0.35	0.32
Median	µg/L	0.48	0.65	0.46	0.35	0.32
95th Percentile	µg/L	0.58	0.66	0.49	0.45	0.43
Maximum	µg/L	0.58	0.66	0.49	0.45	0.43
Mean	µg/L	0.52	0.65	0.46	0.35	0.32
Median	µg/L	0.50	0.65	0.46	0.35	0.32
95th Percentile	µg/L	0.62	0.66	0.49	0.45	0.43
Maximum	µg/L	0.62	0.66	0.49	0.45	0.43
Mean	µg/L	0.50	0.65	0.46	0.35	0.32
Median	µg/L	0.47	0.65	0.46	0.35	0.32
95th Percentile	µg/L	0.61	0.66	0.49	0.45	0.43
Maximum	µg/L	0.61	0.66	0.49	0.45	0.43
Mean	µg/L	0.42	0.65	0.44	0.87	0.77
Median	µg/L	0.42	0.65	0.45	0.87	0.78
95th Percentile	µg/L	0.42	0.65	0.48	1.23	1.01
Maximum	µg/L	0.42	0.65	0.48	1.24	1.02

Shading = exceedance of treatment target

Zinc

The background concentration of Zinc in the Perch Creek watershed ranged between 1.5 to 11.4 µg/L (Table 5.4.2-12). In all scenarios and all assessment nodes in the Perch Lake watershed, slight incremental increases in concentrations were projected, which data remained consistent with background concentrations, and therefore below the BV (Table 5.4.2-12), with the following exceptions. Similar to Lead and Iron, slightly higher upper bound projections compared to the background concentrations (i.e., the 95th percentile and maximum modelled concentrations) were projected for Scenario 4 at PCW and PCO.

Table 5.4.2-12: Water Quality Modeling Results for Zinc

Zinc	Units	ESW	PL2	PL	PCW	PCO
Benchmark Value	µg/L	30				
Background Concentration	µg/L	6.1	1.5	11.4	4.9	n/a
Mean	µg/L	7.08	1.61	1.77	1.37	1.23
Median	µg/L	6.85	1.58	1.74	1.35	1.20
95th Percentile	µg/L	8.17	1.77	1.89	1.75	1.68
Maximum	µg/L	8.17	1.77	1.89	1.75	1.68
Mean	µg/L	7.37	1.66	1.78	1.38	1.24
Median	µg/L	7.10	1.61	1.75	1.36	1.21
95th Percentile	µg/L	8.69	1.87	1.90	1.76	1.69
Maximum	µg/L	8.70	1.87	1.90	1.76	1.69
Mean	µg/L	6.88	1.55	1.75	1.35	1.22
Median	µg/L	6.65	1.53	1.72	1.33	1.19
95th Percentile	µg/L	7.98	1.62	1.88	1.74	1.67
Maximum	µg/L	7.99	1.62	1.88	1.74	1.67
Mean	µg/L	6.08	1.50	1.70	6.56	5.79
Median	µg/L	6.08	1.50	1.67	6.54	5.84
95th Percentile	µg/L	6.08	1.50	1.85	10.54	8.67
Maximum	µg/L	6.08	1.50	1.85	10.66	8.75

Shading = exceedance of treatment target

Mercury

The background concentration of Mercury in the Perch Creek watershed ranged between 0.006 to 0.028 µg/L (Table 5.4.2-13). In all scenarios, mean and median Mercury concentrations at all assessment nodes in the Perch Lake watershed remained below the BV of 0.23 µg/L (Table 5.4.2-13). This is also the case for the upper bound projections (i.e., the 95th percentile and maximum modelled concentrations, with the exception of Scenarios 1 and 2 at ESW. Higher incremental concentrations were also projected for Scenarios 1 and 2 at PL2, and for Scenario 4 at PCW and PCO.

Table 5.4.2-13: Water Quality Modeling Results for Mercury

Mercury	Units	ESW	PL2	PL	PCW	PCO
Benchmark Value	µg/L	0.23				
Background Concentration	µg/L	0.009	0.011	0.028	0.006	n/a
Mean	µg/L	0.25	0.03	0.01	0.01	0.01
Median	µg/L	0.19	0.02	0.01	0.01	0.01
95th Percentile	µg/L	0.51	0.05	0.01	0.01	0.01
Maximum	µg/L	0.51	0.05	0.01	0.01	0.01
Mean	µg/L	0.32	0.03	0.01	0.01	0.01
Median	µg/L	0.25	0.03	0.01	0.01	0.01
95th Percentile	µg/L	0.63	0.07	0.02	0.01	0.01
Maximum	µg/L	0.63	0.07	0.02	0.01	0.01
Mean	µg/L	0.02	0.01	0.01	0.01	0.01
Median	µg/L	0.01	0.01	0.01	0.01	0.01
95th Percentile	µg/L	0.03	0.01	0.01	0.01	0.01
Maximum	µg/L	0.03	0.01	0.01	0.01	0.01
Mean	µg/L	0.01	0.01	0.01	0.05	0.05
Median	µg/L	0.01	0.01	0.01	0.05	0.05
95th Percentile	µg/L	0.01	0.01	0.01	0.09	0.07
Maximum	µg/L	0.01	0.01	0.01	0.09	0.08

Shading = exceedance of treatment target

Phosphorus

The background concentration of Phosphorus in the Perch Creek watershed ranged between 0.04 to 0.19 mg/L (Table 5.4.2-14), which according to EC (2004) characterizes the waterbodies within the Perch Lake watershed as mesotrophic to eutrophic. In all scenarios, projected Phosphorus concentrations at all assessment nodes in the Perch Lake watershed remained below the BV of 5 mg/L, and were consistent with background concentrations (Table 5.4.2-14). Slightly higher incremental Phosphorus concentrations were projected for PCW and PCO in Scenario 4.

No Phosphorus concentrations were readily available for the Ottawa River for comparison to these data projections; however, phosphate concentrations have been measured in the Ottawa River adjacent to the CNL site ranging from 0.06 to 0.15 mg PO_4/L (or 0.02 to 0.05 mg P/L), which is similar to the projected concentrations for all assessment nodes in Scenarios 1, 2, and 3..

Table 5.4.2-14: Water Quality Modeling Results for Phosphorus

Phosphorus	Units	ESW	PL2	PL	PCW	PCO
Benchmark Value	mg/L	5.0				
Background Concentration	mg/L	0.07	0.06	0.19	0.04	n/a
Mean	mg/L	0.06	0.06	0.04	0.03	0.03
Median	mg/L	0.07	0.06	0.04	0.03	0.03
95th Percentile	mg/L	0.07	0.06	0.05	0.04	0.04
Maximum	mg/L	0.07	0.06	0.05	0.04	0.04
Mean	mg/L	0.06	0.06	0.04	0.03	0.03
Median	mg/L	0.06	0.06	0.04	0.03	0.03
95th Percentile	mg/L	0.07	0.06	0.05	0.04	0.04
Maximum	mg/L	0.07	0.06	0.05	0.04	0.04
Mean	mg/L	0.09	0.06	0.04	0.03	0.03
Median	mg/L	0.08	0.06	0.04	0.03	0.03
95th Percentile	mg/L	0.11	0.06	0.05	0.04	0.04
Maximum	mg/L	0.11	0.06	0.05	0.04	0.04
Mean	mg/L	0.07	0.06	0.04	0.14	0.12
Median	mg/L	0.07	0.06	0.04	0.14	0.12
95th Percentile	mg/L	0.07	0.06	0.05	0.22	0.18
Maximum	mg/L	0.07	0.06	0.05	0.22	0.18

Aluminum

The background concentration of Aluminum in the Perch Creek watershed ranged between 74 to 333 µg/L (Table 5.4.2-15). This concentration range is well above the BV for Aluminum of 50 µg/L. In all scenarios for all assessment nodes in the Perch Lake watershed, projected data are above the BV, but remain within the background data range (Table 5.4.2-15). Negligible to slight incremental increases in Aluminum are discernible at each assessment node; however, projected concentrations for PL are much lower than background concentration.

Table 5.4.2-15: Water Quality Modeling Results for Aluminum

Aluminum	Units	ESW	PL2	PL	PCW	PCO
Benchmark Value	µg/L	50				
Background Concentration	µg/L	126	129	333	74	n/a
Mean	µg/L	110	128	87	68	61
Median	µg/L	114	128	88	68	61
95th Percentile	µg/L	124	129	94	86	82
Maximum	µg/L	124	129	94	86	83
Mean	µg/L	105	127	87	68	61
Median	µg/L	110	128	88	68	61
95th Percentile	µg/L	123	129	94	86	82
Maximum	µg/L	123	129	94	86	83
Mean	µg/L	126	129	88	68	61
Median	µg/L	126	129	88	68	61
95th Percentile	µg/L	126	129	94	86	83
Maximum	µg/L	126	129	94	86	83
Mean	µg/L	126	129	86	71	64
Median	µg/L	126	129	86	71	63
95th Percentile	µg/L	126	129	93	86	83
Maximum	µg/L	126	129	93	86	83

Shading = exceedance of treatment target

Barium

Background concentrations of Barium in the Perch Creek watershed are not available (Table 5.4.2-16). With the Exception of ESW and PCW for some scenarios, all projected concentrations of Barium at the assessment nodes in the Perch Lake Watershed remained below the BV of 4 µg/L (Table 5.4.2-16). Concentrations higher than the BV were projected at ESW in Scenarios 1, 2, and 3 with a maximum projected concentration of 18.8 µg/L (Scenario 2). In Scenario 4, where untreated liquid waste is modelled to spills into Perch Creek due to cover failure, Barium concentrations at the downstream nodes PCW and PCO, up to a maximum concentration of 86.8 µg/L, were projected.

Background Barium data in the Ottawa River adjacent to the CNL site were not available for this study.

Table 5.4.2-16: Water Quality Modeling Results for Barium

Barium	Units	ESW	PL2	PL	PCW	PCO
Benchmark Value	µg/L	4.0				
Background Concentration	µg/L	n/a	n/a	n/a	n/a	n/a
Mean	µg/L	7.1	0.5	0.1	0.1	0.1
Median	µg/L	5.5	0.4	0.1	0.1	0.1
95th Percentile	µg/L	15.0	1.2	0.2	0.2	0.2
Maximum	µg/L	15.0	1.2	0.2	0.2	0.2
Mean	µg/L	9.3	0.7	0.2	0.1	0.1
Median	µg/L	7.3	0.5	0.2	0.2	0.1
95th Percentile	µg/L	18.7	1.6	0.2	0.2	0.2
Maximum	µg/L	18.8	1.7	0.2	0.2	0.2
Mean	µg/L	7.4	0.4	0.1	0.1	0.1
Median	µg/L	5.2	0.3	0.1	0.1	0.1
95th Percentile	µg/L	17.6	1.1	0.2	0.1	0.1
Maximum	µg/L	17.7	1.1	0.2	0.1	0.1
Mean	µg/L	0.0	0.0	0.0	47.1	41.3
Median	µg/L	0.0	0.0	0.0	47.1	42.1
95th Percentile	µg/L	0.0	0.0	0.0	85.6	70.5
Maximum	µg/L	0.0	0.0	0.0	86.8	71.3

Shading = exceedance of treatment target

Manganese

Background concentration data for Manganese in the Perch Creek watershed were not readily available (Table 5.4.2-17). In all scenarios, Manganese concentrations at all assessment nodes in the Perch Lake watershed remain below the BV of 120 µg/L (Table 5.4.2-17), with the exception of PCW and PCO in Scenario 4, which projected a maximum concentration of 280 µg/L at PCW.

Table 5.4.2-17: Water Quality Modeling Results for Manganese

Manganese	Units	ESW	PL2	PL	PCW	PCO
Benchmark Value	µg/L	120				
Background Concentration	µg/L	n/a	n/a	n/a	n/a	n/a
Mean	µg/L	8	0.5	0.1	0.1	0.1
Median	µg/L	6	0.4	0.2	0.1	0.1
95th Percentile	µg/L	16	1.3	0.2	0.2	0.2
Maximum	µg/L	16	1.3	0.2	0.2	0.2
Mean	µg/L	10	0.8	0.2	0.2	0.1
Median	µg/L	8	0.5	0.2	0.2	0.1
95th Percentile	µg/L	20	1.8	0.3	0.2	0.2
Maximum	µg/L	20	1.8	0.3	0.2	0.2
Mean	µg/L	24	1.4	0.4	0.3	0.3
Median	µg/L	17	1.0	0.4	0.3	0.3
95th Percentile	µg/L	57	3.4	0.5	0.4	0.4
Maximum	µg/L	57	3.4	0.5	0.5	0.4
Mean	µg/L	0.0	0.0	0.0	152	133
Median	µg/L	0.0	0.0	0.0	152	136
95th Percentile	µg/L	0.0	0.0	0.0	276	227
Maximum	µg/L	0.0	0.0	0.0	280	230

Shading = exceedance of treatment target

5.4.2.7.2.2 Model Results Summary and Discussion

The projected water quality for the screened parameters of potential concerns from GoldSim surface water mass balance model may be summarized in the following key points.

- Projected Lead, Zinc, and Phosphorus concentrations exhibited no exceedances across all assessment nodes in all scenarios in comparison to their respective BVs.
  - The potential for increased algae blooms and eutrophication is predicted to be negligible as Phosphorus concentrations were determined to be well below the BV at all nodes and in all scenarios.
  - For each of these parameters, slightly higher incremental concentrations relative to background concentrations were evident at PCW and PCO.

- Projected Cadmium, Mercury, and Barium concentrations exhibited intermittent cases of BV exceedances at assessment node ESW (during Scenarios 1 and 2; Scenario 3 as well for Barium). Projected Cadmium, Barium, and Manganese concentrations were higher than the BV at assessment nodes PCW and PCO (during Scenario 4).
  - Projected Cadmium exceedances were noted at ESW and PCW only for the 95th percentile and maximum results.
- Projected Copper, Iron, and Aluminum concentrations were higher than their respective BVs at all assessment nodes in all scenarios. However, for each of these parameters, their background concentrations were also higher than their BVs.
- The Ottawa River is expected to adequately rapidly assimilate any discharge from the Perch Lake Watershed under all scenarios to existing conditions in the river, such that aquatic life and drinking water sources are unlikely to be affected.

5.4.2.8 Prediction Confidence and Uncertainty

This section discusses how uncertainty was conservatively addressed such that predicted residual effects are not underestimated. The surface water analysis was conducted with moderate confidence in background data available to provide an overview of the potential changes in surface water quality in the Perch Lake catchment and confluence of the Ottawa River. Mitigation for construction and operations activities is based on accepted and proven best management practices, as well as practices already in use at the CNL property (e.g., sediment and erosion control, runoff management, dust management).For the GoldSim model, the main limitation rests with the lack of daily or monthly water quantity and water quality data for each model node. Furthermore, the model was run with annual flow averages from 969 to 1980, with background water quality concentrations for the Perch Lake watershed sourced from 2010 to 2015 data. If high temporal resolution (daily) flow data is available in the future and for long-term overlapping time periods, GoldSim will be able produce more accurate results inclusive of seasonal variation and long-term annual trends. Additionally, current point-estimate concentration results may be presented with their respective confidence intervals should high temporal resolution (daily) water quality data becomes available. The lack of readily available background concentrations for the Ottawa River limited model performance in assessing the resultant fully mixed conditions at the confluence of Perch Creek outlet and the Ottawa River. Predicted residual effects are not expected to be underestimated due to following factors that have contributed to conservatism in the modelling projections.

- Treated leachate concentrations were modelled in Scenarios 1 and 2 where removal efficiencies were based on ideal conditions in pilot wastewater treatment studies. In reality, due to variations in pH and temperature for example, removal rates are not expected to be as efficient as those determined from the pilot study. However, measured operational treatment data will be evaluated and used to update the water quality projections, if and as necessary.
- Untreated leachate concentrations were used in the modelled Scenarios 3 and 4 in the post-closure and post-institutional phases when the WWTP would no longer be in operation. It is considered unlikely that these concentrations will be associated with these scenarios, but they have been used as a reasonable conservative assumption.

- In all scenarios, the model was run without decay or sorption mechanisms, whereas in actuality concentrations may be subject to chemical and biological processes that remove them from the mass balance as they progress downstream.
- Background concentrations obtained from previous reports were typically presented as 5-year averages, which include data measured below detection. For data measured below detection, the detection level was used in the averaging calculation; the true background concentrations may not have been as high as used. Nonetheless, these as-stated averages used in the model were considered to be a conservative estimate of the background concentrations.

5.4.2.9 Monitoring and Follow-up

Routine surface water quality monitoring is ongoing as part of CNL's Environmental Monitoring Program which will be continued for the Project. Environmental monitoring will be completed to verify effects predictions and will continue through operations, closure and post-closure phases (Table 5.4.2-18). Surface water monitoring in the receiving environment is integrated into the CNL Environmental Monitoring Program. In addition, operational monitoring will be completed to verify the surface water management pond is performing as designed and to demonstrate compliance with site-specific effluent limits developed for the NSDF Project. The effluent water quality monitoring will be integrated into the CNL Effluent Verification Monitoring Program.

Table 5.4.2-18: Monitoring and Follow-up Programs for Surface Water Quality

Valued Component	Project Phase and Potential Effect	Monitoring Program Objective	Conceptual Monitoring Program	Suggested Duration	Implementing Program
Surface Water Quality	■ Discharge of treated effluent from the WWTP to the East Swamp Wetland can cause changes to downstream surface water quality. ■ Leakage of leachate from the ECM during the post-closure phase (i.e., after Year 2400) from liner and cover failure as a result of normal evolution can cause changes to downstream surface water quality.	Environmental monitoring – Verify EA predictions related to surface water quality.	Monitor the quality of surface water surrounding the ECM footprint area to evaluate whether the quality of the water is impacted by the ECM or by operation of surface water management pond(s)	Water quality monitoring will continue through operations, closure and post-closure. The number of parameters and locations may change based annual review of monitoring data.	Surface water monitoring in the receiving environment is integrated into the CNL Environmental Monitoring Program.
		■ Operational monitoring – Verify the surface water management pond is performing as designed. ■ Demonstrate compliance with site-specific effluent limits developed for the NSDF Project.	■ Visual inspections and surface water sampling will be carried out to identify leachate seeps, characterize the surface water chemistry in perimeter ditches in relation to applicable surface water protection objectives, and determine if contingency measures are warranted. ■ Each pond weir outlet water quality will be sampled identify if any contact surface water or leachate contamination of the non-contact surface water were occurringis entering the surface water management ponds. ■ WWTP effluent verification monitoring consistent with CSA Standard N288.5-11.	■ Routine visual inspections and surface water sampling during operation, closure, and post-closure, as required. ■ Effluent monitoring will continue throughout operation of the WWTP.	Effluent water quality monitoring will be integrated into the CNL Effluent Verification Monitoring Program.

5.4.2.10 Conclusions

Valued components refer to environmental features that may be affected by a project and that have been identified to be of concern by the proponent, scientists, government agencies, Aboriginal peoples, or the public (The Agency 2014). Surface water quality is recognized as an important component of the environment that may be affected by the NSDF Project and changes to surface water quality could, in turn, lead to effects on other VCs selected for assessment. Acknowledging that changes to surface water quality are considered to be important aspects of the natural and human environment, surface water quality is referred to as an intermediate component. Results of the analysis of changes in measurement indicators for surface water quality are provided to other disciplines for inclusion in their assessment.

Residual effects to surface water quality are primarily associated the operation of the WWTP and treated and untreated effluent discharge during the operations and post-closure phases (Table 5.4.2-19). During operations and closure, treated effluent is discharged into the East Swamp wetland with ultimate discharge to Perch Creek. The strategy for wastewater treatment is based on optimizing public and environmental protection by defining an approach to wastewater treatment that uses best demonstrated available technology that is economically achievable (BDATEA), and capable of meeting regulatory requirements. In addition, the treatment target for effluent is the CRL Acceptability Criteria for Routine and Non Routine Discharge of Liquids to Stormwaters. Treated effluent will be sampled and confirmed that it meets treatment targets before release to East Swamp Wetland.

During the post-closure phase (i.e., after Year 2400), leakage of leachate from the ECM from liner and cover failure as a result of normal evolution can cause changes to downstream surface water quality. The final cover system will be constructed to promote the shedding of surface water to mitigate infiltration into the mound, and minimize leachate generation. In addition, environmental monitoring will be completed throughout the post closure phase for the NSDF Project to confirm that the cover is functioning as intended.

The GoldSim surface water mass balance model results revealed the following key points:

- Projected Lead, Zinc, and Phosphorus concentrations exhibited no exceedances across all assessment nodes in all scenarios in comparison to their respective BVs.
- Projected Cadmium, Mercury, and Barium concentrations exhibited intermittent cases of BV exceedances at assessment node ESW (during Scenarios 1 and 2; Scenario 3 as well for Barium). Projected Cadmium, Barium, and Manganese concentrations were higher than the BV at assessment nodes PCW and PCO (during Scenario 4).
- Projected Copper, Iron, and Aluminum concentrations were higher than their respective BVs at all assessment nodes in all scenarios. However, for each of these parameters, their background concentrations were also higher than their BVs.
- The Ottawa River is expected to adequately rapidly assimilate any discharge from the Perch Lake Watershed under all scenarios to existing conditions in the river, such that aquatic life and drinking water sources are unlikely to be affected.

Surface water monitoring in the receiving environment is integrated into the CNL Environmental Monitoring Program. In addition, operational monitoring will be completed to verify the surface water management pond is performing as designed and to demonstrate compliance with site-specific effluent limits developed for the NSDF Project. The effluent water quality monitoring will be integrated into the CNL Effluent Verification Monitoring Program.

Table 5.4.2-19: Summary of Predicted Residual Adverse Effects for Surface Water Quality Valued Component

Valued Components	Residual Adverse Effects	Project Effect Occurs in	Contributing Project Activity	Proposed Mitigation
Surface Water Quality	Discharge of treated effluent from the WWTP to the East Swamp Wetland can cause changes to downstream surface water quality	Operations and Closure	Discharge of treated effluent to the Perch Creek drainage basin.	■ The strategy for wastewater treatment is based on optimizing public and environmental protection by defining an approach to wastewater treatment that uses best demonstrated available technology that is economically achievable (BDATEA), and capable of meeting regulatory requirements. ■ The treatment target for effluent is the CRL Acceptability Criteria for Routine and Non Routine Discharge of Liquids to Stormwaters. ■ Treated effluent will be sampled and confirmed that it meets treatment targets before release to East Swamp Wetland ■ An exfiltration gallery is proposed at the discharge outlet to promote the exfiltration of treated water into the local groundwater regime. ■ Appropriate procedures to identify emergency spill occurrences and response, as well as appropriate response to non-contact surface water or leachate contamination will also be implemented as described in the Operations and Maintenance Plan and Contingency Plan

Valued Components	Residual Adverse Effects	Project Effect Occurs in	Contributing Project Activity	Proposed Mitigation
Surface Water Quality	Leakage of leachate from the ECM during the post-closure phase (i.e., after Year 2400) from liner and cover failure as a result of normal evolution can cause changes to downstream surface water quality.	Post-closure	Liner and cover failure as a result of normal evolution	■ The final cover is designed to promote positive drainage from the NSDF Project site and reduce erosion or abrasion of the cover. ■ The final cover system will be constructed to promote the shedding of surface water to mitigate infiltration into the mound, and minimize leachate generation. ■ The cover system design incorporates a series of shallow, trapezoidal, riprap-lined drainage channels that are designed to convey water at low velocity. ■ The perimeter road ditch will route the runoff around the ECM perimeter to minimize ponding of water into the closed ECM, erosion of the cover and underlying waste materials, destabilization of the ECM structure, and damage to access roads. ■ The ECM final grading and drainage plan includes collection ditches along the top of the ECM berm road to collect side slope drainage. ■ Environmental monitoring will be completed throughout the post-closure phase for the NSDF Project to confirm that the cover is functioning as intended.

5.5 Aquatic Environment

This section of the Environmental Impact Statement (EIS) for the Canadian Nuclear Laboratories (CNL) Near Surface Disposal (NSDF) Project seeks to understand and characterize potential residual effects of the NSDF Project on aquatic biodiversity. Effects of the NSDF Project are considered in the context of cumulative effects from other past, present, and reasonably foreseeable developments on aquatic biodiversity.

5.5.1 Scope of the Assessment

Section 5.5 focuses on providing an assessment for aquatic biodiversity. Aquatic biodiversity includes fish and fish habitat. The aquatic biodiversity assessment follows the overall environmental assessment approach and methods described in Section 5.1. The assessment was completed by applying the following key steps.

- **Step 1 – Identify Valued Components (VCs) and define the spatial boundaries, temporal boundaries, assessment cases, assessment endpoints, and measurement indicators** (refer to Sections 5.5.1.2 Valued Components and Section 5.5.1.3 Assessment Boundaries). This step frames the assessment by defining the assessment boundaries and focusing the assessment on the most important components of aquatic biodiversity that have the potential to be adversely affected by the NSDF Project.
- **Step 2 – Describe the existing conditions** (refer to Section 55.1.4 Description of the Environment). This step describes the existing conditions of the environment for each VC within the spatial boundaries selected for the assessment. The existing conditions are the outcome of the historical and current environmental pressures that have shaped the observed patterns in the environment for aquatic biodiversity VCs.
- **Step 3 – Evaluate Project interactions and mitigation** (refer to Section 5.5.1.5 Project Interactions and Mitigation). This step begins by describing the components and/or activities associated with the NSDF Project that have the potential to interact with aquatic biodiversity. Next, the potential effects of each interaction are considered using a pathway analysis, which identifies mitigation options for each potential effect and evaluates whether mitigation is sufficient to break the pathway such that the potential to cause residual effects to aquatic biodiversity is rendered negligible or eliminated altogether. Where effects are adequately mitigated, they are not carried forward for further analysis. The rational for concluding the assessment at this step for those pathways is articulated.
- **Step 4 – Identify monitoring and follow-up** required to confirm effects predictions and address uncertainty (refer to Section 5.5.8 Monitoring and Follow-up).
- **Step 5 - Present a consolidated summary of conclusions and outcomes of the assessment** (refer to Section 5.5.10 Conclusions). This is the final step of the assessment and summarizes the results of the assessment and highlights any key concerns for aquatic biodiversity raised during the assessment.

It is important to note that the following environmental assessment steps outlined in Section 5.1 were not required as there were no primary pathways identified in the aquatic biodiversity assessment:

- present the methods and results of the residual effects analysis;
- describe the level of certainty and management of uncertainty; and,
- classify and determine the significance of the predicted residual effects.

Each assessment step integrates information from regulatory guidelines, scientific literature, the experience of the professionals conducting the assessment, and issues raised during engagement activities. Information and areas of interest raised by the public, communities of interest, regulators, and First Nation and Métis communities during engagement that influenced the scope of the aquatic biodiversity assessment are summarized in Table 5.5.1-1. Other general areas of interest and questions raised during the engagement that pertain to the aquatic biodiversity assessment (if any) are documented in Appendix 4.0-22 Formal Public Feedback.

Table 5.5.1-1: Summary of Areas of Interest Raised During Engagement Activities that Influenced the Scope of the Aquatic biodiversity Assessment

Area of Interest	How the Area of Interest Was Included in the Assessment
Effects to fish from potential for contamination in the Ottawa River from the NSDF Project.	The spatial boundaries of the assessment were selected to include consideration of potential effects to the Ottawa River. Surface water modelling was completed to estimate contaminant concentrations within the Perch Creek basin. Meeting guidelines within the Perch Creek basin is considered to be protective of fish in the Ottawa River.

5.5.2 Valued Components

Valued components refer to environmental features that may be affected by a project and that have been identified to be of concern by the proponent, scientists, government agencies, Aboriginal peoples, or the public (The Agency 2014). Fish and fish habitat are recognized as important components of the aquatic environment that may be affected by the NSDF Project and changes to fish and fish habitat could, in turn, lead to effects on other VCs, such as land and resource use (Section 5.9).

The assessment of aquatic biodiversity focused on predicting changes to species of fish that use the Perch Creek basin, including large-bodied and small-bodied species, species occupying various trophic levels (e.g., carnivores, invertivores, and herbivores), and species that use shoreline habitat near Point au Baptême in the Ottawa River (Table 5.5.2-1). Species, such as Lake Sturgeon (*Acipenser fulvescens*), American Eel (*Anguilla rostrata*), River Redhorse (*Moxostoma carinatum*), and Northern Brook Lamprey (*Ichthyomyzon fossor*), which occur in the Ottawa River and are species of conservation concern (Government of Canada 2016), are not identified as specific VCs in the aquatic biodiversity assessment because their species distributions and preferred habitats lie outside the Regional Study Area (i.e., downstream of any expected measurable changes to surface water quality; RSA). As most, if not all, of the previously recorded species of fish at the Chalk River Laboratories (CRL) property can be part of a commercial, recreational, or Aboriginal fishery (CRA), the inclusion of all fish species as a "fish" VC in the environmental assessment is consistent with Fisheries and Oceans Canada's (DFO's) Fisheries Protection Policy (DFO 2013).

Table 5.5.2-1: Valued Components for Aquatic Biodiversity Assessment

Valued Component	Rationale for Selection
Fish	■ Up to 15 species have been documented within the Perch Lake watershed, some of which may use habitat in the Ottawa River at the mouth of Perch Creek. ■ Species in potentially affected waters are part of a commercial, recreational, or Aboriginal (CRA) fishery (DFO 2013), for example, Northern Pike (Esox lucius), Brown Bullhead (Ameiurus nebulosus) and supporting forage fish species. ■ Societal values concerning changes in local fisheries species are an important consideration in understanding potential effects of the NSDF Project.
Fish Habitat	■ Wetlands, lakes, streams and rivers provide a diversity of functions for life history stages of CRA fish species, and forage fish that support CRA species. ■ The NSDF Project may affect existing availability of the spatial and temporal distribution of habitat, which can subsequently affect land and resource use.

A functioning ecosystem involves interactions of multiple species ranging in size and complexity from bacteria to apex predators. Each species is likely to respond differently to physical effects to habitat, as well as levels of substances present in environmental media. As such, the aquatic VCs selected for the Environmental Risk Assessment completed for the NSDF Project (summarized in Section 5.7) were selected to assess exposures to water, as well as ingestion of aquatic biota (Table 5.5.2-2). Common species with a wide geographic range are often used in Environmental Risk Assessment to represent less common species with similar feeding habits because common species have better-known exposure factors and toxicity values. Valued components selected for the Environmental Risk Assessment are presented in Section 5.7.

Assessment endpoints represent the key properties of each VC that should be protected (Table 5.5.2-2). The assessment endpoint for fish and fish habitat is maintenance of self-sustaining and ecologically effective fish populations, which are important components of ongoing fisheries productivity. Self-sustaining fish populations are healthy and viable and, by definition, robust and capable of withstanding environmental change and accommodating stochastic processes (Reed et al. 2003).

Habitat availability, habitat distribution, and survival and reproduction were selected as the measurement indicators for the aquatic biodiversity species VCs (Table 5.5.2-2). The measurement indicators are defined as follows:

- **Habitat availability**: changes to the amount of habitat (e.g., by altering flows or abundance of food) and quality of habitat (e.g., by altering water quality or noise).
- **Habitat distribution**: changes to spatial configuration and connectivity of habitats.
- **Survival and reproduction**: changes to abundance caused by altering survival and/or recruitment (i.e., demographic parameters).

Table 5.5.2-2: Assessment Endpoints and Measurement Indicators for the Aquatic Biodiversity Assessment

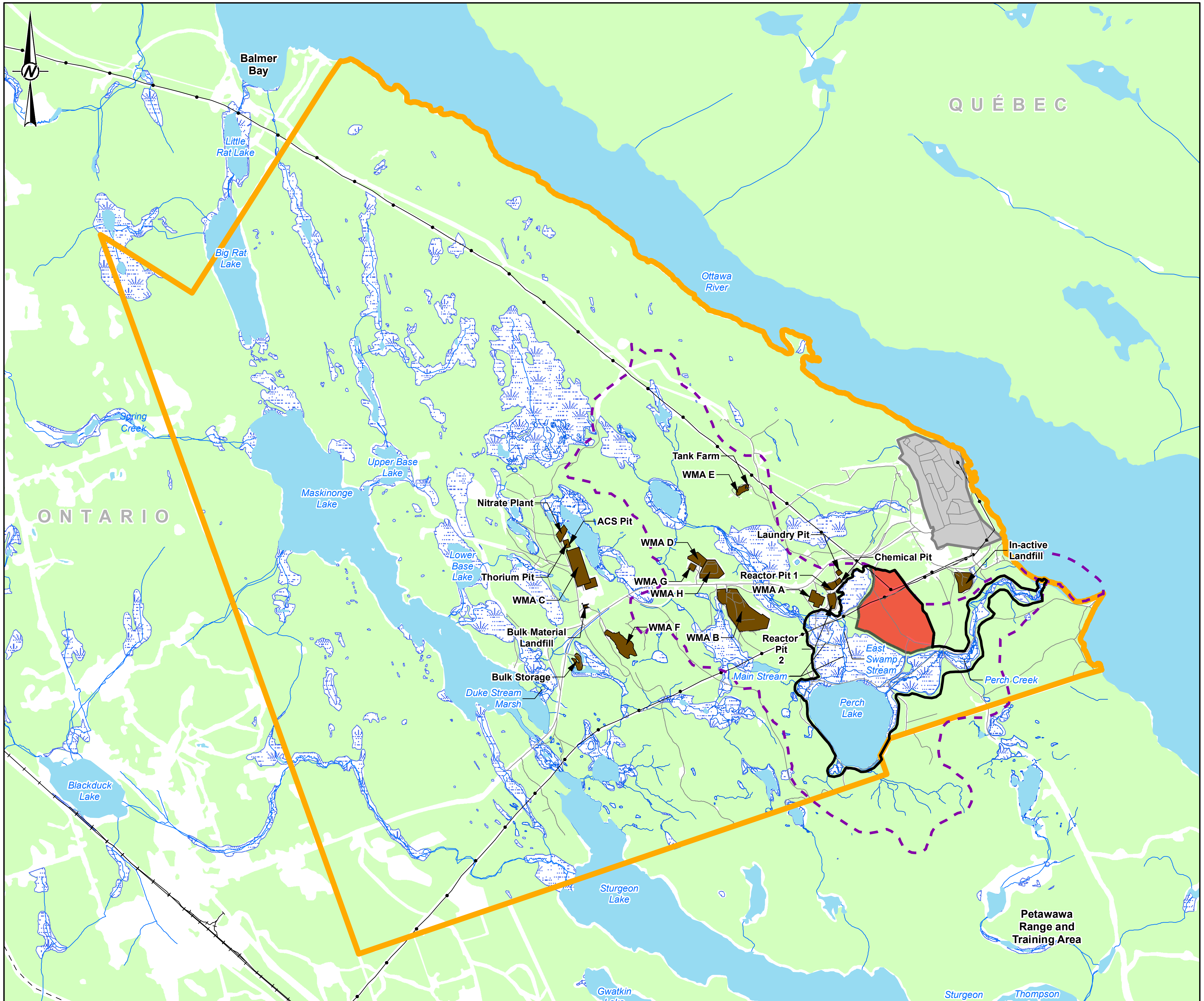
Valued Component	Assessment Endpoints	Measurement Indicators
Fish	■ Self-sustaining and ecologically effective fish populations ■ Ongoing fisheries productivity	■ Habitat availability (quality and quantity) ■ Habitat distribution ■ Survival and reproduction
Fish Habitat	■ Ongoing support of fisheries productivity	■ Habitat availability (quality and quantity) ■ Habitat distribution

5.5.3 Assessment Boundaries

5.5.3.1 Spatial Boundaries

The spatial boundaries selected for the aquatic biodiversity assessment were chosen because they permit description of existing conditions in sufficient detail to enable potential project-VC interactions and effects to be identified, understood, and assessed, including understanding and assessing the contribution of the NSDF Project to cumulative effects. The spatial boundaries selected for the aquatic biodiversity assessment are the same as those identified for hydrology and surface water quality and are presented on Figure 5.5.3-1 and are described below.

- **Site Study Area (SSA):** the SSA is the NSDF Project footprint (i.e., where project activities would be undertaken including the NSDF Project's proposed facilities, buildings and infrastructure).
- **Local Study Area (LSA):** The LSA is defined as the area within which there is potential for measurable changes to measurement indicators resulting from the proposed NSDF Project activities. The LSA includes the SSA and is bounded by Perch Lake and Perch Creek, and adjacent wetlands and swamps.
- **Regional Study Area (RSA):** The RSA is defined as the area within which the potential effects of the NSDF Project may interact with the effects of other existing or reasonably foreseeable projects. The RSA is determined by the spatial extent of the Perch Lake watershed, and includes Perch Lake and its tributaries, and Perch Creek. Although the Ottawa River in the vicinity of the mouth of Perch Creek is included in the RSA, the river beyond this location lies outside the boundary of the assessment.



LEGEND

- ROADS
- RAILWAY
- HYDRO LINE
- NATURAL GAS PIPELINE
- RIVER/STREAM
- WATERBODY
- WETLAND
- WOODED AREA
- SITE STUDY AREA (NDSF PROJECT SITE)
- CRL MAIN CAMPUS
- CRL PROPERTY
- WASTE MANAGEMENT AREA (WMA)[1]
- LOCAL STUDY AREA
- REGIONAL STUDY AREA

1 0 1
1:35,000 KILOMETERS

NOTE(S)
1. LIQUID DISPOSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.

REFERENCE(S)
1. BASEDATA ONTARIO MNRF 2016, CANVEC 2016, AND CNL 2016
2. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
3. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18N

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
SPATIAL BOUNDARIES SELECTED FOR THE AQUATIC ENVIRONMENT ASSESSMENT

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	MM
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.5.3-1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:
25mm

This page left intentionally blank

5.5.3.2 Temporal Boundaries

Temporal boundaries (i.e., project phases) establish the timeframe during which NSDF Project effects are assessed. The temporal boundary represents the timeframe during which project activities are actively occurring, and considers the duration of predicted residual effects. The duration of an effect is defined as the amount of time between the start and end of a Project activity or stressor (which is related to the project phases) plus the time required for the residual effect to be reversed. In some cases, a residual effect may be irreversible within the temporal boundaries of the Project or if the effects were predicted to last so far into the future that they could not be predicted with any level of certainty (e.g., residual effect lasts for thousands of years). The following phases were identified for the NSDF Project:

- **Construction Phase**: includes site preparation and all activities associated with the construction of the NSDF. This phase includes activities such as installing the necessary supporting and/or ancillary facilities and NSDF infrastructure to facilitate NSDF operations, inactive commissioning and systems testing, and transportation of construction materials. Construction activities are expected take place from 2018 to 2020.
- **Operations Phase**: includes all activities associated with the landfilling of waste receipt, waste placement, water management, wastewater treatment plant operations, vehicle movements into and from the NSDF Project site, and maintenance activities. Operations activities are expected to last approximately 50 years (i.e., 2020 to 2070).
- **Closure Phase:** includes activities necessary to complete the installation of the final cover and implementation of long-term monitoring. Closure activities are expected to start in 2070 and continue through to 2100, after which the NSDF Project will transfer into the post-closure phase.
- **Post-closure Phase:** has two discrete periods: Institutional Control and post-Institutional Control. The Institutional Control period includes implementation of both active and passive control throughout 2100 to 2400 (i.e., 300 years). During Institutional Control, groundwater monitoring and groundwater quality management will continue to demonstrate compliance with the safety case assumptions. Post-institutional Control occurs after year 2400 and continues indefinitely.

The temporal boundaries for the aquatic biodiversity assessment include consideration of effects of the NSDF Project from construction through to post-closure.

5.5.3.3 Assessment Cases

The assessment cases considered in the aquatic biodiversity assessment include the Base Case and Application Case.

- **Base Case –** This scenario represents existing conditions and characterizes combined effects from previous and existing developments and activities. The Base Case reflects the effects of existing disturbances, such as forestry, transportation, agricultural, mining, and residential and recreational development. Current effects from the existing CRL facilities and operations, for example, are considered part of the Base Case.
- **Application Case –** This scenario represents predictions of the effects of the Base Case combined with the effects that may result from the NSDF Project. The Application Case considers potential effects from the NSDF Project during construction through to the closure and post-closure phase.
- **Reasonably Foreseeable Development (RFD) Case** – This scenario represents predictions of the cumulative effects of the Application Case, which includes the Base Case, plus projects that are currently under application review or that have officially entered a regulatory application process, and are therefore, considered reasonably foreseeable. There are no RFDs expected in the CRL property (i.e., the RSA) with the exception of new/upgrades to research and development facilities, new support infrastructure, and ongoing decommissioning and environmental restoration activities. New support infrastructure and research and development facilities will be located within existing disturbed areas on the CRL property (i.e., no disturbance to Greenfield areas). Potential effects from these activities are not expected to spatially overlap with potential effects to aquatic biodiversity from the NSDF Project. The end-state plan for the CRL site will be to return lands disturbed by site activities to a condition that is physically stable, and safe in keeping with the land use and landscape of the day. Therefore, decommissioning and environmental restoration activities are anticipated to positively affect fish and fish habitat. Because RFDs will have no spatial overlap and are likely to positively affect the fish and fish habitat, an RFD Case is not presented as part of this assessment.

5.5.4 Description of the Environment

5.5.4.1 Methods

This section describes the setting and characterization for the aquatic biodiversity as relevant for the assessment of effects from the NSDF Project. It describes the existing conditions (i.e., Base Case) against which potential changes from the NSDF Project are compared and evaluated. Existing fish and fish habitat conditions within and surrounding the CRL property, including the Ottawa River, were obtained from published reports and available baseline data.

5.5.4.2 Results

5.5.4.2.1 Fish Habitat

The NSDF Project is located entirely within the Perch Lake watershed of the RSA (Figure 5.5.3-1) at the southern edge of the Canadian Shield in the Ottawa River valley (Robertson and Barry 1985). Ground surface elevations range from a low of approximately 160 metres above sea level (masl) within the low-lying and relatively flat terrain bordering the north side of Perch Lake, to a high of 196 masl along the crest of the ridge to the east of Emergency Road #3 (ER-3) that separates the Perch Lake and Ottawa River drainage basins.

The watershed includes the Waste Management Areas (WMAs) A and B, the Reactor and Laundry Pits and the Liquid Dispersal Area (LDA). From Perch Lake, surface water (Perch Creek) flows in a north-easterly direction through Perch Creek to its confluence with the Ottawa River. The Perch Creek basin drains approximately 18% of CRL property area and drains to the Ottawa River through Perch Lake and Perch Creek (CNL 2016).

The Ottawa River section near the CRL property is 200 to 400 metres (m) wide, slow-moving, and with a shoreline dropping quickly to a depth of 55 m. There is a shallow shelf extending across Point au Baptême (approximately 125 m wide) where Perch Creek enters the Ottawa River. The bottom across the shelf is predominately fine substrate, with average depths of 1 to 3.5 m, and aquatic vegetation is abundant around the shoreline.

Physical characteristics of Perch Lake include a wetted area of approximately 45 hectares (ha), a drainage area of 730 ha, a maximum depth of 3.5 m, and a mean depth of 2 m (Robertson and Barry 1985). In late summer and fall, the water level usually drops by as much as 0.25 m. Most of Perch Lake is open water except for littoral zones along the shore, including a region of floating, emergent and submerged vegetation, which amounts to about 30% of the lake's surface (Yankovich et al. 2000).

The dominant vegetation form in Perch Lake is a floating-leafed plant cover of fragrant water-lily (*Nymphaea odorata*) and watershield (*Brasenia schreberi*). Closer to the shore, narrow leafed emergent bands of slender sedge (*Carex lasiocarpa*), twig rush (*Cladium mariscoides*) and broad-leaved arrowhead (*Sagittaria latifolia*) grow in profusion in the shallow water, as does common cattail (*Typha latifolia*) and pickerelweed (*Pontederia cordata*). In the deeper water beyond, fully or partially submerged vegetation, dominated by common bladderwort (*Utricularia vulgaris*), flat-leafed bladderwort (*Utricularia intermedia*), fennel-leafed pondweed (*Potamogeton pectinatus*), big-leaf pondweed (*Potamogeton amplifolius*) and stoneworts (*Chara* sp.), grows along the bottom. Along the north shore and elsewhere, a broad leafed emergent cover of pickerelweed (*Pontederia cordata*) contrasts with water-lilies. The outer fringe of this zone is known as Perch Lake Marsh. This open marsh may be considered to be part of the lake, with which it is physically continuous. To the north, there are extensive wetlands, notably Perch Lake Swamp, South Swamp, East Swamp and West Swamp. The lake is confined, in part, by sand outcrops along the northern and southern shores, and by bedrock along the western shores.

Mean annual flows at the outlet of Perch Lake are 0.057 cubic metres per second (m^3/s) based on the 11-year average water budget (1969 to 1980) for the hydrologic year (September 1 to August 31; see Section 5.4.1.4.2). Downstream of the outlet, Perch Creek ranges from 5 to 10 m in width and generally has a depth of less than 1 m. The Perch Creek weir (PCW) is located at the downstream extent of adjacent wetlands, approximately 700 m downstream of Perch Lake (Photo 5.5.4-1).

Photo 5.5.4-1: Upstream View of the Perch Creek Weir, August 2012

Below the Perch Creek weir, the creek enters a mixed deciduous woodlot and overhead cover increases substantially (Sowden and Power 1981). Stream gradient also increases sharply, exceeding a 10% slope in sections. A series of small waterfalls (or cascades) occur just downstream of the weir, which is expected to be a major barrier to upstream movements of fish, preventing access to upper Perch Creek and Perch Lake. The waterfalls then lead to a pool riffle sequence, followed by slow flowing water in the lower reach of the creek. The substrate in the middle reach is rock, gravel, and coarse sand; whereas the substrate in the lower section of the creek is dominated by silt and sand substrate. The overall slope of Perch Creek is approximately 3%.

Flow rates from the Perch Creek weir were measured by CNL from 2009 to 2015 (see Table 5.4.1-6 and in Figure 5.4.1-3). The highest flows typically occur in conjunction with spring melt (i.e., freshet) events in April, while lower flows are encountered during the summer season, particularly in August. The overall annual average flow from years 2009 to 2015 was estimated to be approximately 0.063 m^3/s.

5.5.4.2.2 Fish Inventory

An inventory of fish of a variety of habitats (nine waterbodies) within the CRL property was performed in summer 1980 (Sowden and Power 1981), with follow-up inventory investigations performed in 1996 and 1997 (CG&S 1997, 1998). The baseline inventory data, although over 20 years old, provides a historical baseline description that can be used to characterize the potential distribution of species in the assessment area. Current distributions may also reflect the introduction of Northern Pike to Perch Lake in the mid-to-late 1980s (Yankovich et al. 2000). It is expected that the species composition of Perch Lake has not measurably changed since the late 1980s, in part, because of the cascade on Perch Creek acting a natural barrier for any upstream movements of species in the Ottawa River.

Names of waterbodies that were sampled as part of historical baseline studies include the following: Ottawa River, Perch Lake, Lower Bass Lake, Upper Bass Lake, Maskinonge Lake, Perch Creek (Perch Lake outlet), Main Stream (tributary to Perch Lake), East Swamp Stream (tributary to Perch Lake), and Duke Stream Marsh (Figure 5.5.3-1). Sampling gear types included experimental gill nets, hoop net traps, beach seines, minnow traps, and backpack electrofisher. Historical data on distribution, diet, and growth of locally occurring fish species, with a focus on environments below waste disposal sites are provided in more detail in Sowden and Power (1981).

Forty-one fish species were collected during the 1980 field program, including 13 species collected in the Perch Lake watershed (Table 5.5.4-1; Sowden and Power 1981). One species (Blacknose Shiner) recorded in Perch Lake during earlier investigations (Ophel and Fraser 1971) was not captured in the watershed in 1980, and two species (Rosyface Shiner and Threepsine Stickleback) were recorded near the mouth of Perch Creek but not in the creek or upstream locations. Within the Perch Creek watershed, seven species were exclusive to lower Perch Creek, including Common Shiner, Longnose Dace, Fallfish, White Sucker, Johnny Darter, Logperch, and Mottled Sculpin. It is assumed that species found in lower Perch Creek (i.e., below the Perch Creek weir) also occur in the Ottawa River near the outlet of Perch Creek (e.g., shelf habitat near Point au Baptême) to meet their life history requirements (e.g., for foraging, overwintering). Species with relatively wide distributions in the Perch Lake watershed and also dominant species in upper Perch Creek included Fathead Minnow, Pearl Dace, and Creek Chub. Abundant cyprinid species in Perch Lake included Bluntnose Minnow and Pearl Dace, and the dominant large-bodied species in the lake included Yellow Perch (40.4% of catch), Brown Bullhead (24.2% of catch), and Pumpkinseed (15.5% of catch). The dominant species in Main Stream were Pearl Dace and Fathead Minnow, and the only species captured in East Swamp Stream was Pearl Dace.

Table 5.5.4-1: Historical Distributions of Focal Species Identified within or near the Chalk River Property

Common Name	Scientific Name	Trophic Category[(a)]	Feeding Habitat[1]	Distribution Across Nine Waterbodies/Watercourses based on Sowden and Power (1981)	Occurrence at Main Stream and Upper Perch Creek based on CG&S (1997, 1998)
Common Shiner	*Luxilus cornutus*	Invertivore-herbivore	Generalist	Lower Perch Creek	—
Blacknose Shiner[2]	*Notropis heterolepsis*	Invertivore-herbivore	Generalist	Ottawa River (shoreline)	Upper Perch Creek
Rosyface Shiner	*Notropis rubellus*	Invertivore	Specialist	Ottawa River (shoreline near Perch Creek)	—
Bluntnose Minnow	*Pimetheles notatus*	Omnivore	Generalist	All locations sampled in Sowden and Power (1981) except Upper Bass Lake and tributaries to Perch Lake	Upper Perch Creek
Fathead Minnow	*Pimetheles promelas*	Omnivore	Generalist	Duke Stream Marsh, Main Stream, Perch Lake, upper Perch Creek	Main Stream, Upper Perch Creek
Longnose Dace	*Rhinichthys cataractae*	Insectivore	Benthic	Lower Perch Creek	—
Creek Chub	*Semotilus atromaculatus*	Omnivore	Generalist	Perch Lake, upper/lower Perch Creek, and Ottawa River in vicinity of Perch Creek	Main Stream, Upper Perch Creek
Fallfish	*Semotilus corporalis*	Invertivore-carnivore	Generalist	Ottawa River (shoreline) and lower Perch Creek	—
Pearl Dace	*Semotilus margarita*	Invertivore	Water column	Perch Lake, Main Stream, East Swamp Stream, and lower/upper Perch Creek	Main Stream, Upper Perch Creek
White Sucker	*Catostomus commersonii*	Omnivore	Benthic	Widely distributed, but not recorded in upper Perch Creek, Perch Lake and tributaries to Perch lake	—
Brown Bullhead	*Ictalurus nebulosus*	Omnivore	Benthic	Perch Lake, upper/lower Perch Creek, Maskinonge Lake, and Ottawa River	Upper Perch Creek
Threespine Stickleback*	*Gasterosteus aculeatus*	Invertivore-carnivore	Generalist	Ottawa River (shoreline near Perch Creek)	—

Table 5.5.4-1: Historical Distributions of Focal Species Identified within or near the Chalk River Property

Common Name	Scientific Name	Trophic Category[(a)]	Feeding Habitat[1]	Distribution Across Nine Waterbodies/Watercourses based on Sowden and Power (1981)	Occurrence at Main Stream and Upper Perch Creek based on CG&S (1997, 1998)
Pumpkinseed	*Lepomis gibbosus*	Invertivore-carnivore	Generalist	Perch Lake, upper/lower Perch Creek, Maskinonge Lake, Lower Base Lake, and Upper Base Lake	Upper Perch Creek
Yellow Perch	*Perca flavescens*	Invertivore-carnivore	Water column	Widely distributed, but not recorded in Duke Stream Marsh and in Perch Lake tributaries	—
Johnny Darter	*Etheostoma nigrum*	Invertivore	Benthic	Maskinonge Lake, Upper Base Lake, Ottawa River (near Perch Creek), and Lower Perch Creek	—
Logperch	*Percina caprodes*	Invertivore	Benthic	Ottawa River (near Perch Creek), and lower Perch Creek	—
Mottled Sculpin	*Cottus bairdii*	Invertivore	Benthic	Maskinonge Lake, Ottawa River (near Perch Creek), and lower Perch Creek	—

a) Considers species descriptions in Scott and Crossman (1973).

Northern Pike (*Esox lucius*), a top carnivore, was introduced to Perch Lake in mid-to-late 1980s; 2 Blacknow Shiner reported in Perch Lake by Ophel and Fraser (1971).

Following the baseline investigations by Sowden and Power (1981), Northern Pike was introduced to Perch Lake in the mid-to-late 1980s, causing changes to the population dynamics of local species of fish (Yankovich et al. 2000). The once highly productive population of Yellow Perch described in Sowden and Power (1981), was reduced in size, and forage species, such as Creek Chub, Bluntnose Minnow, Fathead Minnow, Pearl Dace and Blacknose Shiner were similarly affected. However, the Perch Lake watershed is expected to continue to support the same species recorded in 1980, and Perch Lake is expected to continue to support a productive fishery characterized by populations of Brown Bullhead and Pumpkinseed, with Brown Bullhead as the most numerous species of fish in the lake (Table 5.5.4-1). Brown Bullhead comprised 80% of the fish catch in Perch Lake using electro-fishing and gill netting methods in 1997 (Yankovich et al. 2000).

Electro-fishing of triburaty streams of Perch Lake and upper Perch Creek in 1996 and 1997 characterized a fish community of Fathead Minnow, Creek Chub, and Pearl Dace in Main Stream, and a community dominated by Creek Chub and Blacknose Shiner in upper Perch Creek (CG&S 1997, 1998; see Table 5.5.4-1). Other species captured in upper Perch Creek included Fathead Minnow, Pearl Dace, Pumpkinseed, and Brown Bullhead. Factors influencing the presence of fish in streams in the RSA appear to be related to flow conditions (e.g., volume), the presence of available refugia, such as pools, during the summer and winter, and the connectivity to Perch Lake (CG&S 1998).

On-going non-radioactive environmental monitoring results indicate that surface water quality of the Perch Lake basin continue to be affected by past operations of the WMAs; however the potential risk to negatively affecting fish and fish habitat is deemed low (CNL 2015, 2016).

5.5.5 Project Interactions and Mitigation

5.5.5.1 Methods

This section describes the process by which interactions between NSDF Project components and activities on aquatic biodiversity are identified and evaluated. Potential effect pathways are identified and mitigation developed to eliminate and/or reduce effects is presented. A pathways analysis is then used to focus the assessment on key interactions between the NSDF Project and the environment by evaluating the different effect pathways to determine if, after incorporation of mitigation, there is still potential to cause residual effects. Where effects will be adequately mitigated, pathways are not forwarded for further analysis (i.e., secondary pathways, or where mitigation will remove the pathway altogether), and the reasons for concluding the assessment at this stage are articulated. Primary pathways that may lead to residual effects after incorporation of mitigation are further characterized in subsequent subsections of the assessment, as required. This section helps to focus the remainder of the assessment on those interactions (effects pathways) likely to result in residual adverse effects.

The first part of the analysis was to identify the potential effects pathways for all phases of the NSDF Project. The next step in the analysis was the development of environmental design features and mitigation that could be incorporated into the NSDF Project to eliminate or reduce adverse effects to aquatic biodiversity. Environmental design features included project design elements, environmental best practices, and management policies and procedures. Environmental design features and mitigation were developed through an iterative process between the NSDF Project's engineering and environmental teams, combined with input from NSDF Project-specific or regional engagement with other interested parties. The design features and mitigation were selected considering their effectiveness for implementation and maintenance, and their appropriateness within the context of the identified effect pathways.

After incorporation of mitigation, potential pathways were evaluated into the following categories using scientific knowledge, logic, experience with similar developments, and the effectiveness of environmental design features and mitigation:

- **No linkage pathway –** pathway is removed by environmental design features or mitigation such that the NSDF Project would not be expected to result in a measurable environmental change relative to Base Case values and therefore would have no residual effects to aquatic biodiversity.
- **Secondary pathway –** the pathway could result in a measurable minor environmental change, but would have a negligible residual effect on aquatic biodiversity relative to Base Case (or available guideline values), and is not expected to contribute cumulatively to other NSDF Project effects or to the effects of other past, present or reasonably foreseeable developments to cause a significant effect.
- **Primary pathway –** the pathway is likely to result in an environmental change relative to the Base Case or available guideline values that could contribute to residual effects to aquatic biodiversity.

Environmental design features and mitigation that have been or could be incorporated into the NSDF Project to eliminate and reduce adverse effects were considered. Potential pathways that were completely removed due to implementation of environmental design or mitigation were not assessed further. Pathways that were assessed to be secondary and were demonstrated to have a negligible residual effect to aquatic biodiversity through simple qualitative or semi-quantitative evaluation of the pathway were also not advanced for further assessment. Primary pathways were carried forward for more detailed quantitative and qualitative effects analysis to characterize the residual effects of the NSDF Project.

5.5.5.2 Results

Pathways through which all phases of the NSDF Project may interact with, and result in changes to measurement indicators for aquatic biodiversity are provided in Table 5.5.5-1.

This page left intentionally blank

Table 5.5.5-1: Pathways Analysis for Aquatic Biodiversity Valued Components

<table>
<tr><th>Project Activity</th><th>Effects Pathways</th><th>Management Practices and Mitigation Actions</th><th>Pathway Assessment</th></tr>
<tr>
<td rowspan="3">Project activities during the construction phase:
Site Preparation
Construction of the Engineered Containment Mound (ECM)
Blasting (as required)
Development of surface water management structures
Construction of the Waste Water Treatment Pond (WWTP) and other support facilities
On-site road and access development</td>
<td>Change to local hydrology from surface disturbances may cause changes to water levels, flows and channel/bank stability at downstream locations, affecting water and sediment quality, and fish and fish habitat</td>
<td>The NSDF Project footprint has been designed to avoid wetlands and limit disturbance to the natural environment to the extent feasible. For example, as the ECM is developed sequentially, undeveloped cells may be prepared and used as stockpile areas to store overburden soils to be used during construction or for daily/interim cover stockpiles. This approach reduces the required area for the laydown and stockpile of materials.
A 30 m buffer is established along all identified wetlands near the NSDF site.
Erosion and sediment control practices (e.g., silt fences, runoff management) applicable to the region and already in place at the CNL property will be used during construction around disturbed areas, where appropriate.
During the construction phase, erosion and sediment control measures in place to mitigate the effects of sediment transport include the use of erosion control blankets, as needed, to control erosion on steep slopes, check dams in ditches and swale.
Surface water from all external areas will be conveyed by ditches, swales and culverts to surface water management ponds to address water quality and water quantity criteria established for the wetland receiving waters and, ultimately, Perch Creek.
Where drainage crosses roadways, culverts are sized to convey the 25-year design event without road overtopping.
The surface water management ponds are designed to address erosion and sediment control concerns during construction by providing interim sediment control and by providing water quality/quantity controls during operations, closure, and post-closure.
Annual maintenance activities will identify any erosion problems.
A maintenance review will be completed after major storm events and after the annual springmelt to confirm there are no major erosion issues.</td>
<td>Secondary</td>
</tr>
<tr>
<td>Surface water drainage through the Project site during construction of the engineered containment mound (ECM) may transport blasting residuals and metals directly into downstream waterbodies, affecting surface water and sediment quality, and fish and fish habitat.</td>
<td rowspan="2">A Blasting Plan will be developed and implemented for the NSDF Project.
Runoff from the Project site will be managed where appropriate (e.g., surface water management ponds) to avoid adverse environmental effects in downstream waterbodies.
Additional guidance for the NSDF Project blasting limits will be obtained from the Ontario Provincial Standard Specification (OPSS) in the document OPSS 120 – General Specification for Use of Explosives (OPS 2014).
Blasting activities will follow industry standard Best Management Practices, applicable federal regulations, and Fisheries and Oceans Canada (DFO) guidelines for use of explosives.
Set-back distances required for blasting will be identified in the Blasting Plan.
Any runoff in contact with blasting residues at the NSDF Project site will be managed where appropriate (e.g., surface water management ponds) during the construction phase.</td>
<td>Secondary</td>
</tr>
<tr>
<td>Blasting near fish-bearing waterbodies may result in pressure changes and vibrations, and affect fish mortality and reproduction.</td>
<td>No linkage</td>
</tr>
</table>

Table 5.5.5-1: Pathways Analysis for Aquatic Biodiversity Valued Components

Project Activity	Effects Pathways	Management Practices and Mitigation Actions	Pathway Assessment
■ Project activities during the construction phase (as listed above) ■ Project activities during the operation phase: ▪ Staged development of disposal cells in the ECM ▪ On-site transportation of waste and placement in the ECM ▪ Progressive closure of disposal cells and installation of cover ▪ Operation of the WWTP ▪ Existing presence of fencing around perimeter of ECM ▪ Surface water management ▪ Domestic waste (solid and liquid) management; and, ▪ Routine operational management and monitoring activities.	Air and dust emissions (including sulphur dioxide, nitrogen oxides, and particulate matter) and subsequent deposition may cause a change in surface water and sediment quality, affecting fish and fish habitat.	■ Implementation of CNL's Procedure for Management and Monitoring of Emissions, which includes operational control monitoring and verification monitoring. ■ The Dust Management Plan for the NSDF Project will be developed and will include: ▪ restricting or suspending activities if unacceptable amounts of dust are generated due to winds or other site conditions; ▪ use of water spraying or misting techniques (e.g., water trucks) as the primary dust control method; ▪ use of fixatives (e.g., chemical suppressant) for dust control during winter season or shutdown periods, and for use as daily/interim cover; ▪ suspension of excavating, loading, hauling, and dumping operations when wind speeds exceed the specified criterion; and ▪ vehicles that have come into contact with contamination will be required to pass through the vehicle decontamination facility. ■ On-site vehicles and equipment engines will meet Tier 2 emission standards and be maintained in good working order. ■ Limit idling of vehicles on-site.	Secondary
	Discharge of domestic wastewater may cause a change in surface water and sediment quality, affecting fish and fish habitat.	The grey water/sewage will be stored in a holding tank at the NSDF Project site and periodically transferred to the CRL Sewage Treatment Plant.	No linkage
	Surface water runoff from the NSDF site can contain contaminants and suspended solids, which can affect water quality, ultimately leading to changes to fish habitat qualilty, survival and reproduction.	■ Procedures for surface water management will be developed and implemented for the NSDF Project. ■ The target surface water quality objective is provided by the Ministry of Environment and Climate Change (MOECC, formerly the Ministry of the Environment [MOE]) in Stormwater Management Planning and Design Manual (MOE 2003). ■ Surface water from all external areas will be conveyed by ditches, swales and culverts to surface water management ponds that will address water quality and water quantity criteria established for the wetland receiving waters and, ultimately, Perch Creek. ■ The surface water management ponds are designed to address erosion and sediment control concerns during construction by providing interim sediment control and by providing water quality/quantity controls during operations, closure, and post-closure. ■ The current surface water management pond footprints reflect the overall storage required to control post-closure flows to predevelopment levels for the 2-year through to 100-year rainfall events at the site. This volume also contains the storage required for sediment control during construction and water quality control during operations. ■ Where drainage crosses roadways, culverts are sized to convey the 25-year design event without road overtopping.	No Linkage

Table 5.5.5-1: Pathways Analysis for Aquatic Biodiversity Valued Components

Project Activity	Effects Pathways	Management Practices and Mitigation Actions	Pathway Assessment
Project activities during the operations and closure phases: ■ Surface water management ■ Operation of the WWTP ■ Discharge of treated effluent from the WWTP	Discharge of treated effluent from the WWTP to the East Swamp Wetland can cause changes to groundwater quality in the wetland and downstream surface water quality, which can affect fish habitat, survival and reproduction	■ The strategy for wastewater treatment is based on optimizing public and environmental protection by defining an approach to wastewater treatment that uses best demonstrated available technology that is economically achievable (BDATEA), and capable of meeting regulatory requirements. ■ The treatment target for effluent is the CRL Acceptability Criteria for Routine and Non Routine Discharge of Liquids to Stormwaters. ■ Treated effluent will be sampled and confirmed that it meets treatment targets before release to East Swamp Wetland ■ An exfiltration gallery is proposed at the discharge outlet to promote the exfiltration of treated water into the local groundwater regime. ■ Appropriate procedures to identify emergency spill occurrences and response, as well as appropriate response to non-contact surface water or leachate contamination will also be implemented as described in the Operations and Maintenance Plan and Contingency Plan	Secondary
	Discharge of treated effluent from the WWTP and outlet from the surface water management ponds can scouring of the wetlands, which can affect fish habitat availability.	■ Discharge of treated effluent to the exfiltration gallery area will help to reduce water loss from the hydrogeological system. ■ Outlet flows from all three surface water management ponds will be dispersed by level spreaders that will provide an even flow distribution to the wetland with an appropriately wide dispersal pattern. ■ The WWTP system's outlet utilizes a headwall which discharges to a level spreader for the purposes of preventing erosion and sedimentation at the outlet for the exfiltration gallery. ■ Current surface water management ponds outlet locations are limited by the site boundary (greater than 5 m separation required) so that there is no discharge from the spreader directly to the wetland. ■ Annual maintenance activities will identify any erosion problems. ■ A maintenance review will be completed after major storm events and after the annual spring melt to confirm there are no major erosion issues.	No Linkage
	Leakage of leachate from the ECM during operations and closure may cause changes to groundwater quality in the wetland and downstream surface water quality, which can affect fish, habitat, survival and reproduction.	■ Design of the ECM includes base contours that have been developed using a herringbone pattern with ridges and valleys to promote leachate transport to the leachate collection system for removal. ■ The base liner design include both primary and secondary liner systems that are designed to have redundancy in case of premature failure and are a combination of natural and synthetic barrier systems. ■ The high-density polyethylene (HDPE) geomembrane for the liner was selected as it is compatible with the leachate generated by the waste and will achieve a long service life. ■ The base liner system will include an underlying compacted clay liner to supplement the primary and secondary liner system. ■ The leachate collection system design will provide accessible access points for inspections, maintenance, repairs and replacements. ■ Sampling of the treated effluent will be completed in accordance with CNL's Management and Monitoring of Emissions Procedure.	No Linkage
Project activities during the closure and post-closure phases: ■ Installation of final ECM cover, restoration and grading of the site ■ On-going long-term performance monitoring, transfer of NSDF Project into Institutional Control	The installation of the final cover of the ECM and decommissioning of Project infrastructure may change downstream discharge, water levels, and channel/bank stability, affecting surface water and sediment quality.	■ The final cover is designed to promote positive drainage from the NSDF Project site and reduce erosion or abrasion of the cover. ■ The final cover system will be constructed to promote the shedding of surface water to mitigate infiltration into the mound, and minimize leachate generation. ■ The cover system design incorporates a series of shallow, trapezoidal, riprap-lined drainage channels that are designed to convey water at low velocity. ■ The perimeter road ditch will route the runoff around the ECM perimeter to minimize ponding of water into the closed ECM, erosion of the cover and underlying waste materials, destabilization of the ECM structure, and damage to access roads. ■ The ECM final grading and drainage plan includes collection ditches along the top of the ECM berm road to collect side slope drainage. ■ Environmental monitoring will be completed throughout the post-closure phase for the NSDF Project to confirm that the cover is functioning as intended.	Secondary
	Leakage of leachate from the ECM during the post-closure phase (i.e., after Year 2400) from liner and cover failure as a result of normal evolution can cause changes to groundwater quality in the wetland and downstream surface water quality, which can affect fish habitat, survival and reproduction.		Secondary

This page intentionally left blank

5.5.5.2.1 No Linkage Pathways

The following pathways were assessed as having no measurable environmental change and hence, no linkage to residual effects on aquatic biodiversity VCs.

- Blasting near fish-bearing waterbodies may result in pressure changes and vibrations, and affect fish mortality and reproduction

Use of explosives near fish-bearing waters has the potential to injure or kill fish. Detonation of explosives in or near water creates compressive shock waves that rapidly rise to high peak pressures then rapidly decrease to below ambient hydrostatic pressure (Wright and Hopky 1998). The rapid decrease in pressure produced by blasting has the potential to negatively affect fish in the vicinity by damaging the swim bladder and other soft organs (Wright 1982). Fish eggs in the area affected by pressure waves can be damaged by the movement of the substrate in which they are embedded (Wright 1982).

The NSDF Project will avoid any impacts to fish and fish habitat through the implementation of set-back distances and by avoiding construction and related blasting activities in waterbodies and watercourses. A detailed Blasting Plan will be developed and will contain contingencies and mitigations to reduce the potential for harm to fish and fish habitat. The Blasting Plan will comply with DFO Guidelines for the Use of Explosives in or Near Canadian Fisheries Waters (Wright and Hopky 1998). Additional guidance will be obtained from the Ontario Provincial Standard Specification (OPSS) in the document OPSS 120 – General Specification for Use of Explosives (OPS 2014). Set-back distances required for blasting will be determined and included in the Blasting Plan. Charge sizes, blasting sequences, and any additional measures required to deaden vibrations (i.e., strategic positioning of aggregate material) will be described in the Blasting Plan.

The use of explosives for the development of the proposed NSDF Project is predicted to not measurably change survival or reproduction measurement indicators for fish species in the LSA. It is therefore anticipated that this pathway has no linkage with fish and fish habitat.

- **Discharge of domestic wastewater may cause a downstream change in surface water and sediment quality, affecting fish and fish habitat**

CNL's Sewage Treatment Plant receives approximately 700 cubic metres (m^3) of grey water/sewage per day from approximately 2,500 staff on the CNL property. An additional workforce of 50 staff will be required for the NSDF Project (see Section 3.12), generating grey water/sewage rates within those observed currently on the CNL property. The grey water/sewage from construction and operation of the NSDF Project will be stored in a holding tank at the NSDF Project site and periodically transferred to the Sewage Treatment Plant. As such, discharge of treated domestic wastewater for the NSDF Project to downstream locations (e.g., Ottawa River) is expected to have no linkage to fish and fish habitat.

- **Surface water runoff from the NSDF site can contain contaminants and suspended solids, which can affect water quality, ultimately leading to changes to fish habitat quality, survival and reproduction.**

The surface water management ponds are designed to address erosion and sediment control concerns during construction by providing interim sediment control and by providing water quality/quantity controls during operations, closure, and post-closure. The current surface water management pond footprints reflect the overall storage required to control post-closure flows to predevelopment levels for the 2-year through to 100-year rainfall events at the site. This volume also contains the storage required for sediment control during construction and water quality control during operations. The target surface water quality objective is provided by the Ministry of Environment and Climate Change (MOECC, formerly the Ministry of the Enviromnet [MOE]) in Stormwater Management Planning and Design Manual (MOE 2003), which reports a 60% total suspended solids (TSS) removal that provides a basic water quality treatment for discharge to the receiving wetland.

During the construction phase, erosion and sediment control measures will be in place to mitigate the effects of soil erosion and sediment transport. The measures include the use of erosion control blankets, as needed, to control erosion on steep slopes, check dams in ditches and swales, and the three proposed surface water management ponds that will be constructed to serve as interim sediment control facilities during construction, and then as stormwater management facilities during the operations, expansion and post-closure periods. Erosion and sediment control practices (e.g., silt fences, runoff management) applicable to the region and already in place at the CRL property (i.e., CNL's Management of Land and Habitat Procedure) will be used around disturbed areas, where appropriate.

Site operations include surface water management for the Engineered Containment Mound (ECM) and all external areas. Surface water from all external areas will be conveyed by ditches, swales and culverts to surface water management ponds that will address water quality and water quantity criteria established for the wetland receiving waters and, ultimately, Perch Creek. Contact surface water drainage from the active cells of the ECM will be to the WWTP. Non-contact surface water drainage from completed cells and yet-to-be-activated cells will be directed either by gravity to the external surface water management system or to temporary holding ponds within the ECM, and then pumped to the three surface water management ponds. There will be a need to address pre-treatment of surface water run-off from the active cells prior to conveyance to the WWTP and a need to establish conveyance mechanisms (gravity and pumping) from the interior of the ECM to the surface water management ponds.

Facility inspections will be completed twice annually to confirm that inlets and outlets are clear of debris and to confirm that there are no major erosion issues at the inlet or outlet. As well, the integrity of berms and outlet structures will be confirmed by visual inspections (e.g., to identify any animal burrowing activity or active soil erosion). Inspections will also include an annual sediment level monitoring component within each pond to identify sediment accumulation rates that may require clean-out requirements. If necessary, pond sediment will be extracted by excavation equipment and will be disposed of based on sediment sampling, testing, and classification according to MOECC standards, or stockpiled, de-watered and re-used on-site for ECM cover operations. Sediment removal will follow procedures identified in the Stormwater Management Planning and Design Manual (MOE 2003).

Roadway, sidewalk, and parking lot winter maintenance activities that may release road salt to the environment, include snow plowing/shoveling and de-icing practices, salt and sand storage and snow stockpiling, removal, and disposal. The current winter maintenance practices outlined in the CRL Salt Management Plan provide for effective management of salt use, and will be applied to the NSDF Project, as necessary. As per the plan, the application of road salt on the NSDF site will be to be limited as salt residual within contact water and/or leachate may compromise the treatment effectiveness of the WWTP systems. Instead, alternative products in winter road management, such as a sand-stone mixtures, are currently being considered.

The implementation of these mitigation measures will reduce the potential for changes to soil, water and vegetation quality from surface water runoff from the NSDF site. As such, this pathway was determined to have no linkage to effects on fish and fish habitat.

- **Discharge of treated effluent from the WWTP and outlet from the surface water management ponds can lead to scouring of the wetlands, which can affect fish habitat.**

The major flow system for all three surface water management ponds will discharge to the adjacent wetland and will be dispersed by level spreaders that will provide an even flow distribution to the wetland with an appropriately wide dispersal pattern. The WWTP outlet uses a headwall that discharges to a level spreader for the purposes of preventing erosion and sedimentation at the outlet. An exfiltration gallery is proposed at the discharge outlet to promote the exfiltration of treated water into the local groundwater regime. The proposed surface water management ponds outlet locations are limited by the site boundary (greater than 5 m separation required) so that there will be no discharge from the spreader directly to the wetland. Local topography between the level spreader and the wetland, as well as any setbacks, has influenced the location of the level spreader on site.

Annual maintenance activities will identify erosion issues. Facility inspections will be completed twice annually to confirm that inlets and outlets are clear of debris and to confirm that there are no major erosion issues at the inlet or outlet. In addition, a maintenance review will be completed after major storm events and after the annual spring melt to confirm there are no major erosion issues at the dispersion outlets. As a result of the design of the surface water management pond outlets, and the proposed low discharge rates (i.e., 1 m^3/hr), the discharge of treated effluent from the WWTP to the East Swamp Wetland is not predicted to result in changes to water levels, flows, and channel/bank stability, that would affect water quality at downstream locations. As a result, this pathway was determined to have no linkage to effects on fish and fish habitat.

- **Leakage of leachate from the ECM during operations and closure may cause changes to groundwater quality in the wetland and downstream surface water quality, which can affect fish habitat quality, survival and reproduction.**

Design of the ECM includes base contours that have been developed using a herringbone pattern with ridges and valleys to promote leachate transport to the leachate collection system for removal. The base liner design includes both primary and secondary liner systems that are designed provide redundancy in case of premature failure and are a combination of natural and synthetic barrier systems. The primary liner includes a leachate collection system with the secondary liner housing a leak detection system. The composite base liner contains perforated high-density polyethylene (HDPE) collection and pipes. The HDPE geomembrane was selected as it is compatible with the leachate generated by the waste and is expected to perform as an effective hydraulic and diffusion barrier over the 500-year design life (see Section 3.5.2.4). The base liner system includes an underlying compacted clay liner to supplement the primary and secondary liner system. The leachate collection system design provides access points for inspections, maintenance, repairs and replacements.

The primary liner system will contain the leachate collection system, and will convey leachate to a single collection point for removal from the mound, for transfer to the WWTP for treatment. The primary liner system serves as the primary source of protection for the natural environment below the mound from leachate migration. The secondary liner system will contain the leak detection system, which will be used to detect leaks in the unlikely event that the primary liner system fails. Leachate collected by the leachate collection system will be pumped to the onsite WWTP for treatment.

Designed berms consist of three main geotechnical elements, or layers, each contributing to the soundness and integrity of the berm itself and the whole ECM. A Slope Stability Analysis was completed to provide the information needed to support the design of the base slopes, sidewalls, and side slopes of the ECM. The Slope Stability Analysis addresses the range of anticipated loading conditions, under both short-term and long-term scenarios, to confirm that the slope designs will satisfy minimum factor-of-safety requirements for stability. Size and shape of the berms and each of the elements and layers were determined using a seismic design basis, including the National Building Code of Canada (NBCCC).

The implementation of the above mitigation will limit the potential for changes to groundwater and surface water quality from the NSDF site. As such, this pathway is determined to have no linkage with fish and fish habitat as there will be no measurable effects on fish habitat quality, and survival and reproduction of fish.

5.5.5.2.2 Secondary Pathways

The following pathways were assessed as potentially having a measurable minor environmental change, but resulting in a negligible residual effect on the aquatic biodiversity VCs relative to the Base Case.

- **Change to local hydrology from surface disturbances may affect downstream water levels, flows and channel/bank stability, affecting surface water and sediment quality.**
- **The installation of the final cover of the ECM and decommissioning of Project infrastructure may change downstream discharge, water levels, and channel/bank stability, affecting surface water and sediment quality.**

Changes to surface flows, water levels, and water quality from NSDF Project construction and decommissioning are expected to be limited using environmental design features and mitigation. The NSDF Project footprint was designed to be as small as possible to limit disturbance to the natural environment to the extent feasible and will avoid stream and wetland habitats. For example, as the ECM is developed sequentially, undeveloped cells may be prepared and used as stockpile areas to store overburden soils to be used during construction or for daily/interim cover stockpiles. This approach reduces the required area for the laydown and stockpile of materials. In addition, a 30 m buffer is established along all identified wetlands near the NSDF site.

All proposed physical works are located within the SSA, affecting a relatively small area (4.1%) of the total contributing basin area for Perch Creek (720 ha; Robertson and Barry 1985). Any changes to existing drainage patterns will largely be restricted to this sub-basin. The total annual volume of contact surface water to be treated is 6,556 m^3. The volume represents approximately 0.38% of the average total outflow from Perch Lake (1,700,000 cubic metres per year (m^3/yr)), or 0.30% of the average total outflow from Perch Creek (2,200,000 m^3/yr). Operational treated effluent discharge is expected to be less than 1 cubic metre per hour (m^3/hr). Flow rates within Perch Creek are approximately 252 m^3/hr; the effluent discharge rate is roughly 0.4% of the average Perch Creek flows and approximately 11.5% of East Swamp Weir flows. Furthermore, the receiving wetlands are expected to buffer the discharge, further reducing flow rates into Perch Creek.

All non-contact and contact surface water will be managed within the NSDF Project site, as per the Surface Water Management Plan that will be developed, reducing the potential for the NSDF Project to affect downstream discharge, water levels, and channel/bank stability. Erosion and sediment control practices (e.g., silt fences, runoff management) applicable to the region and already in place at the CNL property will be used during construction and decommissioning around disturbed areas, where appropriate.

Closure activities include the installation of an engineered cover over the ECM to limit ponding and water infiltration in to the waste. Modification to the drainage ditches and conveyance channels will be made to promote positive drainage from the site and limit erosion or abrasion of the cover. Run-off control for the cover is designed to limit ponding and infiltration of water into the ECM, erosion of the cover and waste material, and destabilization of the structure. The ECM design approach is to control the direction and velocity of the run-off to prevent erosion and abrasion of the cover. Any surface water infiltrating the final cover will be collected by the leachate collection system and sent to the WWTP. The three surface water management ponds will remain to promote infiltration and settlement of suspended solids and restrict discharge rates to the nearby wetland. Decommissioning of the WWTP and all associated surface water management structures will be completed after the leachate quantity and quality no longer requires treatment. In addition, environmental monitoring will be

completed throughout the post-closure phase for the NSDF Project to confirm that the cover is functioning as intended.

Implementation of the above described mitigation measures for the NSDF Project are expected to limit changes to downstream discharge, water levels, and channel/bank stability in Perch Creek such that negligible residual effects are predicted to surface water and sediment quality. As such, negligible effects on fish and fish habitat assessment endpoints are predicted.

- **Surface water drainage through the Project site during construction of the ECM may transport blasting residuals and metals directly into downstream waterbodies, affecting surface water and sediment quality, and fish and fish habitat**

Use of ammonium nitrate/fuel oil (ANFO) and water resistant bulk emulsion explosives during the construction of the ECM has the potential to affect surface water quality in the Perch Creek Basin through runoff coming into contact with residual nitrogen material (e.g., nitrate and ammonia) in the construction area. A Blasting Plan will be developed and implemented for the NSDF Project. The Blasting Plan will comply with DFO Guidelines for the Use of Explosives in or Near Canadian Fisheries Waters (Wright and Hopky 1998). Additional guidance will be obtained from the Ontario Provincial Standard Specification (OPSS) in the document OPSS 120 – General Specification for Use of Explosives (OPS 2014). Set-back distances required for blasting will be identified in the Blasting Plan. Any runoff in contact with blasting residues at the NSDF Project site will be managed according to the Surface Water Management Plan (e.g., surface water management ponds and associated systems) during the construction phase. The use of explosives for the development of the proposed NSDF Project is predicted to result in minor changes in surface water and sediment quality concentrations in the Perch Creek Basin. Therefore, this pathway was determined to have a negligible residual effect on fish and fish habitat assessment endpoints.

- **Air and dust emissions (including sulphur dioxide, nitrogen oxides, and particulate matter) and subsequent deposition may cause a change in surface water and sediment quality, affecting fish and fish habitat**

Construction and operation of the NSDF Project will generate air and dust emissions such as carbon monoxide (CO), oxides of sulphur (SOx includes sulphur dioxide [SO2]), oxides of nitrogen (NOx includes nitrogen dioxide NO_2), particulate matter ($PM_{2.5}$), and suspended particulate matter (SPM). Air emissions such as SOx and NOx can result from the use of fossil fuels in generators, vehicles and machinery. Vehicle exhaust and fugitive dust from unpaved and paved roads is the largest contributor to particulate matter (SPM, PM_{10}, and $PM_{2.5}$) during both construction and operations (Section 5.2.1.6.2).

Examples of mitigation practices implemented to limit predicted residual effects from NSDF Project emissions to air quality (and subsequently to aquatic biodiversity VCs) include:

- implementation of CNL's Procedure for Management and Monitoring of Emissions, which includes operational control monitoring and verification monitoring;
- development and implementation of the Dust Management Plan for the NSDF Project;
- the primary dust control method will include water spraying or misting techniques (e.g., water trucks);

- on-site vehicles and equipment engines will meet Tier 2 emission standards and be maintained in good working order; and,
- limiting idling of vehicles on-site.

Dust control will be conducted to support waste placement operations in accordance with the Dust Management Plan during loading, transportation, placement and compaction operations. Work areas that have the potential for generating dust will require implementation of dust suppression technique. The primary dust control method will include water spraying or misting techniques (e.g., water trucks). Water application is controlled to avoid generation of free liquids. Fixatives (e.g., chemical suppressant) may also be used for dust control during winter season or shutdown periods, and for use as daily/interim cover. The use of fixatives is reviewed prior to application for potential effects on leachate and surface water runoff generated by the ECM.

Vehicle exhaust and fugitive dust from unpaved roads is the largest contributor to particulate matter (SPM, PM_{10}, and $PM_{2.5}$) during both the construction and operations phases. Vehicle exhaust during the construction of the ECM is the largest contributor of NO_x/NO_2 and CO. Predicted concentrations for the Application Case during both construction and operations phases are below applicable air quality guidelines and/or standards (Section 5.2.1.6.2, Table 5.2.1-14). With the implementation of CNL's Management and Monitoring of Emissions Procedure and through the implementation of the Dust Management Plan for the NSDF Project, air and dust emissions and subsequent deposition are expected to result in minor and local changes to surface water quality relative to Base Case conditions. Therefore, this pathway was determined to have negligible effects on fish and fish habitat.

- **Discharge of treated effluent from the WWTP to the East Swamp Wetland can cause changes to groundwater quality in the wetland and downstream surface water quality, which can affect fish habitat quality, survival and reproduction.**

The WWTP for the NSDF Project will be a new, stand-alone facility with a new discharge point. The WWTP will treat leachate generated in the ECM during operations and the closure periods. The strategy for wastewater treatment is based on optimizing public and environmental protection by defining an approach to wastewater treatment that uses best demonstrated available technology that is economically achievable (BDATEA), and capable of meeting regulatory requirements.

The chemical and radionuclide concentrations in leachate are calculated using a partitioning model that assumes that the ratio of the contaminant concentration in the solid phase to the contaminant concentration in the leachate is constant. These factors conservatively estimate the leachate characteristics. The radionuclide concentrations in wastewater are a combination of the leachate concentrations and the leachate volume, combined with the contact water and decontamination volumes. The contact water is assumed to have very low radionuclide concentrations because of the effects of daily ECM cover and water management practices within the disposal cell. Decontamination water is assumed to have the same radiological and chemical characteristics as the wastewater from the ECM. In the absence of quantitative information, non-radioactive waste constituents were developed from, information gathered from other sites and the expected characteristics of wastes to be disposed of in the NSDF. These values present a reasonable and conservative estimate of concentrations in wastewater such that the WWTP design is capable of treating wastewater to meet site-specific treatment targets.

Treated effluent will be sampled and confirmed that it meets treatment targets before release to East Swamp Wetland. Treated effluent from the WWTP will be released to an exfiltration gallery promote the exfiltration of treated water into the local groundwater regime; from here, small quantities of residual contaminants will migrate towards the East Swamp Stream. The East Swamp Stream feeds Perch Lake, which is connected to the Ottawa River through Perch Creek. Residual contaminants from the WWTP effluent will be most concentrated with the East Swamp Stream due to dilution in Perch Lake, Perch Creek and the Ottawa River. Doses to non-human biota exposed to the aquatic habitat of East Swamp Stream were calculated to provide a bounding estimate of potential exposure.

A comprehensive framework for assessing radiological exposure to non-human biota is provided in CSA Standard N288.6-12. Both aquatic and terrestrial species will be exposed to contaminated surface water and sediment in the East Swamp stream, Perch Lake, Perch Creek, and Ottawa River. As dilution will occur in the Perch Lake, Perch Creek and Ottawa River, exposure within the aquatic environment of the East Swamp stream is bounding during the period of leachate management system and WWTP operations. Doses to non-human biota were calculated based on the waterborne and airborne emissions from the ECM. It was conservatively assumed that all species would be exposed to a gamma dose rate of 10 microgray per hour (µGy/h), which is based on the dose constraint of 10 microsieverts per hour (µSv/h) at the NSDF fence line. The predicted doses to all indicator species of concern are below the dose benchmark values specified in CSA Standard N288.6-12. A complete description of the assessment to doses on non-human biota is provided in the Performance Assessment Report for the NSDF Project (CNL 2017), and summarized in Section 5.7.

Although there are no new or planned facilities other than the NSDF that may affect the Perch Lake Basin, many of the site's existing WMAs, including WMAs A and B and the LDA (which includes Reactor Pit 1, Reactor Pit 2 and the Chemical Pit) are also in this basin. Contaminants are transported via groundwater to nearby wetlands, including East Swamp, which will be the recipient water body for the NSDF wastewater. Contaminants released into the Perch Lake Basin migrate to Perch Creek from where they reach the Ottawa River, which is the ultimate receptor for all CRL discharges. The NSDF's contribution to potential effects on populations of non-human biota in the Perch Lake Basin does not result in unacceptable cumulative effects. Estimated doses resulting from historic contamination due to releases from WMAs and LDAs, fall below benchmark values for Perch Lake and Perch Creek. Potential contribution from the NSDF to exposure of aquatic species in East Swamp is less than 1% of the current levels of exposures.

For non-radiological constituents, surface water model scenarios were completed for a select group of constituents of potential concern (COPC) as defined in Section 5.4.2.7.1. Key elements of the COPC selection process included identifying those COPCs that were expected to change as a result of the NSDF Project, those with available guidelines, and those that were expected to be toxic to aquatic organisms. The ten selected COPCs were aluminum, barium, cadmium, copper, iron, lead, manganese, mercury, phosphorus and zinc.

The predicted non-radiological concentrations for the COPCs were compared to effluent limits and to local background at the six water quality nodes (see Section 5.4.2.7.2, Tables 5.4.2-8 to Table 5.4.2-17). The predicted concentrations of lead, phosphorus and zinc met their respective effluent limits and local background concentrations and as such were not retained for further consideration. The predicted concentrations of aluminum, barium, and mercury met their respective aquatic life guidelines; therefore, there are no anticipated risks to aquatic life due from these COPCs during the operations phase (Appendix 5.5-1). Overall, changes to groundwater and surface water quality (and habitat quality) from the discharge of treated effluent are expected to have negligible residual effects on fish and fish habitat.

- **Leakage of leachate from the ECM during the post-closure phase (i.e., after Year 2400) from liner and cover failure as a result of normal evolution can cause changes to groundwater quality in the wetland and downstream surface water quality, which can affect fish habitat quality, survival and reproduction.**

Construction, operation, and closure activities of the ECM are designed to provide a stabilized waste array with the purpose of limiting settlement, and water infiltration. After facility closure, the primary pathway for unintended radionuclide releases from the completed phases of the ECM to the environment would be through the groundwater. The groundwater monitoring program for the operational phase will be continued during the initial period after facility closure, but will gradually be reduced if no radionuclide or chemical constituent migrations are identified.

After the closure of all cells and following the decommissioning work, but prior to the end of the Institutional Control period (assumed to take place in the year 2400), both the liner and the engineered cover of the ECM will be within their 500-year design life. A small quantity of leachate will continue to be generated for a relatively short period of time after installation of engineered covers over all ECM disposal cells. The WWTP will continue to operate for as long as contaminated leachate is being generated.

During the post-closure phase, post-institutional control period (i.e., after year 2400) deterioration in the performance of engineered features of the ECM due to the effects of the environment on the engineered cover, base liner and other components of the containment is expected as part of normal evolution. The vegetative cover over the ECM will be replaced with plants that provide less efficient evapotranspiration, soil may begin to erode as a result of weathering and the engineered cover will begin to deteriorate. Eventually, it is assumed that the waste, having dried out during the post-closure period of Institutional Control, will rehydrate and become partially saturated due to infiltration of precipitation. At this time, one of two plausible scenarios may take place:

- **Leaching Through the Base Liner:** If the base liner fails at this time, then it will provide a pathway for the leachate to enter the groundwater. The rate at which contaminants move through the liner system and the groundwater flow system will in part be controlled by the solubility and sorption interactions that involve specific contaminants. If sufficiently mobile, the contaminants will eventually discharge to Perch Creek and thence to the Ottawa River.
- **Bathtub Effect Overflow Scenario:** If the base liner remains intact, then the infiltrating water will continue to be constrained by the ECM liner and berms. Water will enter the ECM at a rate determined by the degree of failure of the cover and percolate through the waste. Within confines of the berms the ECM will become fully saturated and leachate will discharge to surface at the lowest point of the berm. Depending on the rate of discharge the escaping leachate will infiltrate to the local groundwater flow system and may also flow overland to Perch Creek.

The final cover system will be constructed to promote the shedding of surface water to mitigate infiltration into the mound, and minimize leachate generation. This design also allows for minor differential settlement to occur while maintaining positive surface water drainage. In addition, the cover system design incorporates a series of shallow, trapezoidal, riprap-lined drainage channels that are designed to convey water at low velocity. Where slopes require, channels would include additional rock material to dissipate energy and prevent erosion or transport of materials. The perimeter road ditch will route the runoff around the ECM perimeter where it will then flow into discharge culverts to one of three stormwater ponds located outside the ECM perimeter road.

These run-off controls are designed to minimize ponding of water into the closed ECM, erosion of the cover and underlying waste materials, destabilization of the ECM structure, and damage to access roads. Without controls, run-off could eventually lead to the creation of gullies and ravines that could compromise the integrity of the final cover system and/or the ECM structure.The ECM final grading and drainage plan also includes collection ditches along the top of the ECM berm road to collect side slope drainage.

Due to the presence of multiple barriers and the implementation of the above mentioned erosion controls, the likelihood of either scenario occurring before the end of the ECM design life (500 years) is very low. However, it was conservatively assumed, that one of these scenarios may occur immediately following the end of Institutional Control, which is assumed to take place in year 2400. Both of these release scenarios are considered to be “Normal Evolution” scenarios. A complete description of the assessment to doses on non-human biota is provided in the Performance Assessment Report for the NSDF Project (CNL 2017), and summarized in Section 5.7.

Doses to non-human biota, due to exposure from leakage through the base line or from the bathtub effect during the post-closure phase, were calculated based on the methods specified in CSA Standard N288.6-12. In addition, external gamma dose due to direct exposure to the waste is taken into account. It is conservatively assumed that all species are exposed to a dose rate of 10 µGy/h, which is the limiting criterion at the NSDF fence line. The external radiation is dominant compared to the waterborne pathway, although this is driven by conservatism in assumptions. The predicted doses to non-human biota for both scenarios are below dose benchmark values specified in CSA Standard N288.6-12. As such, changes to groundwater and surface water quality (and habitat quality) from the leakage of leachate from liner and cover failure as a result of normal evolution are expected to have negligible residual effects on aquatic biodiversity.

As described previously, for non-radiological constituents, surface water model scenarios were completed for a select group of COPCs as defined in Section 5.4.2.6.3. The predicted non-radiological concentrations for the COPCs were compared to effluent limits and to local background at the six water quality nodes (see Section 5.4.2.6.4.1, Tables 5.4.2-8 to Table 5.4.2-17). The predicted concentrations of lead, phosphorus and zinc met their respective effluent limits and local background concentrations and as such were not retained for further consideration. The predicted concentrations of aluminum, barium, and mercury met their respective aquatic life guidelines; therefore, there are no anticipated risks to aquatic life due to aluminum, barium and mercury at any assessed water quality node for these COPCs (Appendix 5.5-1).

Cadmium, copper, iron, and manganese had predicted concentrations greater than their respective aquatic life guidelines during the institutional control and post-institutional control periods of the Project, which follow the decommissioning of the WWTP. However, considering the conservative assumptions related to the non-radiological concentrations in the waste material and the conservative assumptions in the water quality modeling (Section 5.4.2), and considering that wastes will be required to meet the facility’s Waste Acceptance Criteria, risks associated with these parameters and phases are expected to have negligible residual effects on fish and fish habitat.

5.5.5.2.3 Primary Pathways

No pathways were identified as having a primary linkage to aquatic biodiversity VCs. As such, a residual effects analysis and assessment of significance is not required for the aquatic biodiversity assessment.

5.5.6 Monitoring and Follow-up

Monitoring and follow-up programs are not specifically identified for aquatic biodiversity; rather, operational monitoring (i.e., sampling of treated effluent in the storage tanks prior to discharge) and monitoring programs developed for groundwater and surface water quality will be implemented (see Section 5.3.2.8 and Section 5.4.2.9, respectively) to verify effects predictions for effects to fish and fish habitat. Water quality monitoring will continue through operations and closure and into post-closure. The number of parameters and locations may change based on annual review of monitoring data. Routine surface water quality monitoring and flow in East Swamp and Perch Creek monitoring is ongoing as part of CNL's Environmental Monitoring Program.

5.5.7 Conclusions

Valued components refer to environmental features that may be affected by a project and that have been identified to be of concern by the proponent, scientists, government agencies, Aboriginal peoples, or the public (The Agency 2014). Fish and fish habitat are recognized as important components of the aquatic environment that may be affected by the NSDF Project and changes to fish and fish habitat could, in turn, lead to effects on other VCs, such as land and resource use. The assessment of aquatic biodiversity focused on predicting changes to species of fish that use the Perch Creek basin, including those that may also use shoreline habitat near Point au Baptême in the Ottawa River.

The assessment endpoint for fish and fish habitat is ongoing fisheries productivity, and the maintenance of self-sustaining and ecologically effective fish populations in support of ongoing fisheries productivity. Self-sustaining fish populations are healthy and viable and, by definition, robust and capable of withstanding environmental change and accommodating stochastic processes (Reed et al. 2003). Maintaining viable fish populations is a conservation target frequently applied by conservation biologists and resource managers (Fahrig 2001; Nicholson et al. 2006; Ruggiero et al. 1994; With and Crist 1995). Habitat availability, habitat distribution, and survival and reproduction were selected as the measurement indicators for the aquatic biodiversity VCs.

The potential for effects to aquatic biodiversity VCs are primarily related to changes in groundwater, and surface water quality. The strategy for wastewater treatment is based on optimizing public and environmental protection by defining an approach to wastewater treatment that uses best demonstrated available technology that is economically achievable (BDATEA), and capable of meeting regulatory requirements. The effluent requirement for treated wastewater is the CRL Acceptability Criteria for Routine and Non-Routine Discharge of Liquids to Stormwaters. Treated effluent will be sampled and confirmed that it meets treatment targets before release to East Swamp Wetland. The predicted doses to all indicator species of concern are below the dose benchmark values specified in CSA Standard N288.6-12.

Although there are no new or planned facilities other than the NSDF that may impact the Perch Lake Basin, many of the site's existing WMAs, including WMAs A and B and the LDA (which includes Reactor Pit 1, Reactor Pit 2 and the Chemical Pit) are also in this basin. Contaminants are transported via groundwater to nearby wetlands, including East Swamp, which will be the recipient water body for the NSDF wastewater. Estimated doses resulting from historic contamination due to releases from WMAs and LDAs, fall below benchmark values for Perch Lake and Perch Creek. Potential contribution from the NSDF to exposure of aquatic species in East Swamp is less than 1% of the current levels of exposures.

Construction, operation, and closure activities of the ECM are designed to provide a stabilized waste array with the purpose of limiting settlement, and water infiltration. After facility closure, the primary pathway for unintended radionuclide releases from the completed phases of the ECM to the environment would be through the groundwater. The groundwater monitoring program for the operational phase will be continued during the initial period after facility closure but will gradually be reduced if no radionuclide or chemical constituent migrations are identified. During the post-closure phase, post-institutional control period (i.e., after year 2400) deterioration in the performance of engineered features of the ECM due to the effects of the environment on the engineered cover, base liner and other components of the containment is expected as part of normal evolution. The predicted doses to non-human biota during the post-closure phase are below dose benchmark values specified in CSA Standard N288.6-12.

Mitigation and environmental design features implemented for the NSDF Project are well-understood and include existing practices at the CNL site. Therefore, measurable residual effects on aquatic biodiversity VCs are not predicted as a result of the NSDF Project. Self-sustaining and ecologically effective populations will be maintained with the application of the Project.

5.6 Terrestrial Environment

This section of the Environmental Impact Statement (EIS) for the Canadian Nuclear Laboratories (CNL) Near Surface Disposal (NSDF) Project seeks to understand and characterize potential residual effects of the NSDF Project on terrestrial biodiversity, including potential effects to the ecological and biological processes that connect species with each other and their abiotic environment. Effects of the NSDF Project are considered in the context of cumulative effects from other past, present, and reasonably foreseeable developments on terrestrial biodiversity.

5.6.1 Scope of the Assessment

Section 5.6 focuses on providing an assessment for terrestrial biodiversity. Terrestrial biodiversity includes all upland vegetation communities and wetlands, as well as terrestrial wildlife taxa (e.g., birds), and wildlife taxa with terrestrial and aquatic life history requirements (e.g., reptiles). Effects of the NSDF Project on aquatic biodiversity (e.g., fish) are assessed in Section 5.5. The terrestrial biodiversity assessment follows the overall environmental assessment approach and methods described in Section 5.1. The assessment was completed by applying the following steps:

- **Step 1 – Identify Valued Components (VCs) and define the spatial boundaries, temporal boundaries, assessment cases, assessment endpoints, and measurement indicators** (refer to Sections 5.6.1.2 Valued Components and Section 5.6.1.3 Assessment Boundaries). This step frames the assessment by defining the assessment boundaries and focusing the assessment on the most important components of terrestrial biodiversity that have the potential to be adversely affected by the NSDF Project.
- **Step 2 – Describe the existing conditions** (refer to Section 5.6.1.4 Description of the Environment). This step describes the existing conditions of the environment for each VC within the spatial boundaries selected for the assessment. The existing conditions are the outcome of the historical and current environmental pressures that have shaped the observed patterns in the environment for each VC.
- **Step 3 – Evaluate Project interactions and mitigation** (refer to Section 5.3.1.5 Project Interactions and Mitigation). This step begins by describing the components and/or activities associated with the NSDF Project that have the potential to interact with terrestrial biodiversity. Next, the potential effects of each interaction are considered using a pathway analysis, which identifies mitigation options for each potential effect and evaluates whether mitigation is sufficient to break the pathway such that the potential to cause residual effects to terrestrial biodiversity is rendered negligible or eliminated altogether. Where effects are adequately mitigated, they are not carried forward for further analysis. The rationale for concluding the assessment at this step for those pathways is articulated. Pathways that may lead to residual effects to terrestrial biodiversity after incorporating mitigation are carried forward to Step 4 for further analysis.
- **Step 4 – Present the methods and results of the residual effects analysis** (refer to Section 5.6.1.6 Residual Effects Analysis). This step outlines the methods used to predict and characterize residual effects to each terrestrial biodiversity VC after mitigation has been applied, and then presents the results of the residual effects analysis.

- **Step 5 – Describe the level of certainty and management of uncertainty** (refer to Section 5.6.1.7 Prediction Confidence and Uncertainty). This step in the assessment evaluate the available literature, data, and models used for the assessment, and describes the level of certainty that can be placed on predicted residual effects. This assessment provides a precautionary evaluation of potential residual effects of the NSDF Project and aims to overestimate potential effects where uncertainty is present. This step identifies how uncertainty was managed for each VC so that the predicted effects of the NSDF Project are not underestimated.
- **Step 6 – Classify and determine the significance of the predicted residual effects** (refer to Section 5.6.1.8 Residual Effects Classification and Determination of Significance). This step describes the methods and presents the results of a residual effects classification and determination of significance for each terrestrial biodiversity VC. The residual effects classification uses a common set of criteria: direction, magnitude, geographic extent, duration, reversibility, frequency, and likelihood to classify effects, and significance is determined in a binary fashion for each VC (i.e., either significant or not significant).
- **Step 7 - Identifying monitoring and follow-up** (refer to Section 5.6.1.9 Monitoring and Follow-up). This step of the assessment identifies monitoring and follow-up required to confirm effects predictions and address uncertainty.
- **Step 8 - Present a consolidated summary of conclusions and outcomes of the assessment** (refer to Section 5.6.1.10 Conclusions). This is the final step of the assessment and summarizes the results of the assessment and highlights any key concerns for terrestrial biodiversity raised during the assessment.

Each assessment step integrates information from regulatory guidelines, scientific literature, the experience of the professionals conducting the assessment, and issues raised during engagement. Information and concerns raised by the public, communities of interest, regulators, and First Nation and Métis communities during engagement that influenced the scope of the terrestrial biodiversity assessment are summarized in Table 5.6.1-1. Other general concerns and questions raised during engagement that pertain to the terrestrial biodiversity assessment (if any) are documented in Appendix 4.0-22 Formal Public Feedback.

Table 5.6.1-1: Summary of Issues Raised during Engagement Activities that Influenced the Scope of the Terrestrial Biodiversity Assessment

Issue	How the Issue Was Included in the Assessment
Inclusion of Migratory Birds in the assessment.	Because of their ecological importance and because they are protected by federal legislation (*Migratory Birds Convention Act (MBCA), 1994*), the suite of migratory birds with the potential to be affected by the NSDF Project were included as a terrestrial biodiversity VC. Some individual migratory birds that are federally-listed species at risk were also included as VCs assessed at the species level.
Concern over the destruction of terrestrial habitat.	An evaluation of the change in habitat availability and habitat distribution from the NSDF Project footprint is completed for each of the wildlife species selected as VCs.
Concern with road mortality to Blanding's turtle and what can be done to reduce this risk.	Increased risk of injury/mortality of Blanding's turtle on roads is a key interaction evaluated as part of the residual effects assessment. Mitigation to be implemented to reduce this risk is described and monitoring programs are recommended for Blanding's turtle.
Inclusion of bird and other species at risk in the assessment	The species level assessment focused on species identified on Schedule 1 of the federal *Species at Risk Act* (SARA). Species at risk evaluated in the assessment include Canada warbler, eastern whip-poor-will, and golden-winged warbler, bats, and Blanding's turtle. Most of the species level VCs identified for the terrestrial biodiversity assessment are useful indicators for broader groups of species.

5.6.2 Valued Components

Valued components refer to environmental features that may be affected by a project and that have been identified to be of concern by the proponent, scientists, government agencies, First Nation and Métis peoples, or the public (The Canadian Environmental Assessment Agency 2014).. Identifying VCs helps to focus the assessment on the most important or representative components of the environment that are likely to be affected by the NSDF Project. This section describes how VCs were selected for the terrestrial biodiversity assessment and identifies the assessment endpoints and measurement indicators that were used to assess the effects of the NSDF Project on each VC. Because this assessment is for a designated project, as described in the *Canadian Environmental Assessment Act, 2012* (CEAA 2012), and is regulated by the Canadian Nuclear Safety Commission (CNSC), VC selection considered guidance from Appendix A of the CNSC's Draft Environmental Protection: Environmental Policy, Assessments and Protection Measures (CNSC 2015). Specifically, VC selection focused on providing a *"full accounting of effects on species with elevated conservation status and their habitat"* (CNSC 2015).

Selection of VCs for the terrestrial biodiversity assessment was accomplished using a coarse and fine filter approach. Coarse filter VCs were identified to permit an assessment of the effects of the NSDF Project to terrestrial biodiversity broadly, whereas fine filter VCs focus the assessment on individual biodiversity features, such as species. Combined, the coarse and fine filter VCs are selected to provide a holistic assessment of the potential effects of the NSDF Project on terrestrial biodiversity.

To capture potential effects to terrestrial biodiversity broadly, the terrestrial vegetation communities potentially affected by the NSDF Project were selected as a VC (Table 5.6.2-1). Assessing and managing biodiversity at the ecosystem level (represented by vegetation communities) means that a large number of biodiversity features are addressed together. Terrestrial vegetation communities also represent the habitats that may support species with elevated conservation status. For example, effects of the NSDF Project on wildlife guilds dependent on very old live trees, standing dead trees (i.e., "snags"), coarse woody debris and natural disturbance processes (fire, insects

and disease) found in mature and older forests will be captured by the vegetation communities VC assessment. Vegetation community types present in the regional study area (RSA) were included as part of the vegetation community VC. Potential effects from the NSDF Project on traditional use vegetation species by First Nations and Métis communities are assessed in Section 5.9 Land and Resource Use.

Because of their ecological importance and because they are protected by federal legislation (*Migratory Birds Convention Act (MBCA), 1994*), the suite of migratory birds with the potential to be affected by the NSDF Project were also included as a coarse filter terrestrial biodiversity VC. The purpose of including the group of migratory birds together as a VC was to identify appropriate mitigation so that the NSDF Project would comply with the MBCA for all migratory birds. Section 5 of the MBCA prohibits the disturbance, destruction or removal of a nest or related shelter, or egg of a migratory bird, or possession of a live migratory bird, or a carcass, nest or egg of a migratory bird. Some individual migratory birds that are federally-listed species at risk were also included as VCs assessed at the species level.

To complement the assessment of vegetation communities and migratory birds, a fine-filter approach was applied at the species level. A fine filter approach at the species level is also important to understand effects to biodiversity features that sometimes are distinct from effects to ecosystems and for which targeted actions at the species level may be required (i.e., as specified in federal action plans or recovery strategies developed for species at risk).

The species level assessment focused on species identified on Schedule 1 of the federal *Species at Risk Act* (SARA). On a federal level, designations for species at risk occurring in Canada are initially determined by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). If approved by the federal Minister of the Environment, species are added to the federal List of Wildlife Species at Risk under Schedule 1 of SARA. Once included on Schedule 1, it is prohibited to kill, harm, harass, capture, possess, collect, buy, sell, or trade individuals, as well as damage or destroy the residence of a species listed as Extirpated, Endangered or Threatened (Government of Canada 2002). Furthermore, species that are included on Schedule 1 as Extirpated, Endangered or Threatened are afforded protection of species-specific critical habitat on federal lands (such as the Chalk River Laboratories [CRL] property), once critical habitat is defined in a recovery strategy.

Baseline biodiversity data have been collected at the CRL property since 2009, with targeted surveys for species at risk occurring annually since 2012. These surveys have determined there are 20 terrestrial species at risk listed on Schedule 1 of SARA that occur within the CRL property (Appendix 5.6-1).

All SARA-listed species identified in Appendix 5.6-1 with confirmed observation records within the CRL property were considered as potential VCs at the species level. Each species was evaluated to determine whether or not its presence was likely in the NSDF Project footprint (Site Study Area) or the Local Study Area (LSA) defined for the terrestrial biodiversity assessment (see Section 5.6.3.1.1). Species with a very low likelihood of occurrence, for which habitat was not present in the LSA, or for which effects of the NSDF Project were unlikely, were excluded as VCs. Rationale for inclusion and exclusion of each species at risk identified during surveys undertaken in the CRL property is presented in Appendix 5.6-1. Species at risk identified as VCs for the terrestrial biodiversity assessment are presented in Table 5.6.2-1. Individual species for which the potential effects of the NSDF Project are similar were grouped into a single VC (e.g., bats; Table 5.6.2-1).

Most of the species level VCs identified for the terrestrial biodiversity assessment are useful indicators for broader groups of species. For example, eastern whip-poor-will (*Antrostomus vociferus*) represents a guild of species that forage on insects while flying through the air and require edge habitat and forest openings (Table 5.6.2-1).

Blanding's turtle is tied closely to wetland habitats and adjacent upland areas and can be used to represent other species at risk with similar requirements, such as snapping turtle. Bats rely on mature forests that contain wildlife trees for roosting habitat, and thus represent a variety of other wildlife tree secondary cavity users (i.e., species that use cavities created by primary cavity excavator species such as woodpeckers). Consequently, understanding the potential effects of the NSDF Project on the selected VCs provides inferences about effects on other wildlife species or guilds with similar life history traits and habitat requirements (Appendix 5.6-1).

Table 5.6.2-1: Valued Components for the Terrestrial Biodiversity Assessment

Valued Component	Rationale for Selection
Vegetation Communities	■ Broadly captures effects on terrestrial biodiversity. ■ NSDF Project is associated with footprint effects that will remove vegetation and result in physical losses of some vegetation communities (and related wildlife habitat).
Migratory Birds	■ Migratory birds and their nests are protected under the federal *Migratory Bird Convention Act, 1994* (MBCA). ■ There are numerous migratory bird species that breed, nest, and take up year-round residence in the vicinity of the NSDF Project. There is the potential for migratory birds to be indirectly and directly affected by the Project through disturbance, habitat loss, and mortality (i.e., vehicle strike on roads or loss of eggs in nests during tree clearing). ■ Comment on the Project Description received by a member of the public specifically requested assessment of this VC.
Canada Warbler	■ Canada warbler (*Cardellina canadensis*) is federally listed as Threatened under SARA and listed under the MBCA. It has legal individual and habitat protection provisions under SARA and individual and nest protection under MBCA. ■ The RSA (CRL property) is federally-owned; therefore, this species is afforded protection of critical habitat because it is listed as Threatened on Schedule 1 of SARA. Critical habitat has not yet been defined for this species in the federal recovery strategy. ■ There is the potential for Canada Warbler to be indirectly and directly affected by the NSDF Project through disturbance, habitat loss, and mortality (i.e., vehicle strike on roads or loss of eggs in nests during tree clearing). ■ Avian species VC recorded within the LSA that represents a guild of early successional habitat specialists requiring coniferous, deciduous, moist mixed forest and regenerating habitats.
Eastern Whip-poor-will	■ Eastern whip-poor-will (*Antrostomus vociferus*) is federally listed as Threatened under SARA and listed under the MBCA. It has legal individual and habitat protection provisions under SARA and individual and nest protection under MBCA. ■ The RSA (CRL property) is federally-owned; therefore, this species is afforded protection of critical habitat because it is listed as Threatened on Schedule 1 of SARA. Critical habitat has been partially defined for this species in the federal recovery strategy. ■ There is the potential for eastern whip-poor-will to be indirectly and directly affected by the NSDF Project through disturbance, habitat loss, and mortality (i.e., vehicle strike on roads or loss of eggs in nests during tree clearing). ■ Keystone avian species VC recorded within the LSA that represents a guild of aerial insectivores requiring open forest/edge habitat in drier deciduous and coniferous habitats.

Table 5.6.2-1: Valued Components for the Terrestrial Biodiversity Assessment

Valued Component	Rationale for Selection
Golden-winged Warbler	■ Golden-winged warbler (*Vermivora chrysoptera*) is federally listed as Threatened under SARA and listed under the MBCA. It has legal individual and habitat protection provisions under SARA and individual and nest protection under MBCA. ■ The RSA (CRL property) is federally-owned; therefore, this species is afforded protection of critical habitat because it is listed as Threatened on Schedule 1 of SARA. Critical habitat has been partially defined for this species in the federal recovery strategy. ■ There is the potential for golden-winged warbler to be indirectly and directly affected by the NSDF Project through disturbance, habitat loss, and mortality (i.e., vehicle strike on roads or loss of eggs in nests during tree clearing). ■ Keystone avian species VC recorded within the LSA that represents a guild of edge habitat specialists.
Bats ■ Little brown myotis ■ Northern myotis ■ Tri-colored bat	■ Little brown myotis (*Myotis lucifugus*), northern myotis (*M. septentrionalis*), and tri-colored bat (*Perimyotis subflavus*) have observation records within the LSA. All three bat species are federally listed as Endangered and have legal individual protection provisions under SARA. ■ The RSA (CRL property) is federally-owned; therefore, these bat species are afforded protection of critical habitat because they are listed as Endangered on Schedule 1 of SARA. Critical habitat has only partially been defined for hibernacula, as the largest threat to these species is associated with that habitat; however, hibernacula have not been found in the study areas and are unlikely to occur in the SSA. Maternity roosts are likely present, and have the potential to be indirectly and directly affected by the NSDF Project through disturbance, habitat loss, and mortality (i.e., loss of roosting bats during tree clearing). ■ There is the potential for bats to be indirectly and directly affected by the NSDF Project through disturbance, habitat loss (loss of roost trees), and mortality (i.e., loss of pre-volant juveniles in maternity roosts during tree clearing). ■ Represents small mammal species recorded in the LSA that rely on wildlife trees (i.e., snags) for part of their life history (maternity roosting, diurnal roosting, and evening roosting).
Blanding's Turtle	■ The Great Lakes/St. Lawrence population of Blanding's turtle (*Emydoidea blandingii*) is federally listed as Threatened and has legal individual and habitat protection provisions under SARA. ■ The RSA (CRL property) is federally-owned; therefore, this species is afforded protection of critical habitat because it is listed as Threatened on Schedule 1 of SARA. Proposed critical habitat has been identified within the CNL property based on the definition in the proposed Recovery Strategy (Environment Canada 2016a). ■ There is the potential for Blanding's Turtle to be indirectly and directly affected by the NSDF Project through disturbance, habitat loss, and mortality (i.e., vehicle strike on roads). ■ Represents reptile species that use a variety of wetland habitats for hibernation, mating, foraging, thermoregulation, staging prior to nesting and for movement. They use upland, relatively open areas with suitable substrate for nesting, overland migration, thermoregulation and foraging. Blanding's turtles display fidelity to their overwintering sites and nesting sites (i.e. use the same habitat year after year).

A functioning ecosystem involves interactions of multiple species ranging in size and complexity from bacteria to apex wildlife predators. Each species is likely to respond differently to physical effects to habitat, as well as levels of substances present in environmental media. As such, the aquatic and terrestrial VCs selected for the

Environmental Risk Assessment completed for the NSDF Project (summarized in Section 5.7) were selected to assess exposures to water, as well as ingestion of aquatic biota. Wildlife species that receive most of their exposure from ingestion of terrestrial plants and animals were also considered. A number of species at risk are known to occur or have the potential to occur in the LSA; however, more common species are often used in Environmental Risk Assessment to represent less common species with similar feeding habits because common species have better-known exposure factors and toxicity values. Valued components selected for the Environmental Risk Assessment are presented in Section 5.7.

Each VC for the terrestrial biodiversity assessment was assessed using the assessment endpoints and measurement indicators listed in Table 5.6.2-2.

Table 5.6.2-2: Assessment Endpoints and Measurement Indicators for the Terrestrial Biodiversity Assessment

Valued Component	Assessment Endpoints	Measurement Indicators
Vegetation Communities	Maintenance of self-sustaining and ecologically effective vegetation communities	■ Ecosystem availability ■ Ecosystem distribution ■ Ecosystem condition
Migratory Birds	Maintenance of self-sustaining and ecologically effective populations	■ Habitat availability ■ Habitat distribution ■ Survival and reproduction
Canada Warbler (*Cardellina canadensis*)		
Eastern Whip-poor-will (*Caprimulgus vociferous*)		
Golden-winged Warbler (*Vermivora chrysoptera*)		
Bats		
Blanding's Turtle (*Emydoidea blandingii*)		

Assessment endpoints represent the key properties of each VC that should be protected. The assessment endpoint for terrestrial biodiversity is the maintenance of self-sustaining and ecologically effective vegetation communities or wildlife populations. Self-sustaining vegetation communities or wildlife populations are healthy and viable and, by definition, robust and capable of withstanding environmental change and accommodating stochastic processes (Reed et al. 2003). Maintaining viable wildlife populations is a conservation target frequently applied by conservation biologists and resource managers (Fahrig 2001; Nicholson et al. 2006; Ruggiero et al. 1994; With and Crist 1995).

Achieving viable wildlife populations, however, may not be sufficient to meet conservation objectives for other species that interact with the VCs being assessed (Soulé et al. 2005). For highly interactive VCs that have strong effects on ecosystem structure and function, the concept of ecologically effective populations was applied as part of the assessment endpoint for wildlife. Likewise, the maintenance of self-sustaining vegetation communities may not be sufficient to support its ecological function on the landscape; therefore, the concept of ecologically effective vegetation communities was applied as part of the assessment endpoint for vegetation communities. Ecologically effective vegetation communities are those that can support the range of native species and ecological and evolutionary processes normally provided by the ecosystem (Noss 1990).

An ecologically effective vegetation communities or wildlife population differs from a self-sustaining vegetation communities or wildlife population if the abundance needed to maintain ecological function is greater than the abundance required to maintain viability for the long-term. The application of the concept of self-sustaining ecologically effective vegetation communities or wildlife populations is key to the significance determination for the terrestrial biodiversity assessment (Section 5.6.7.4).

Two sets of measurement indicators were employed for terrestrial biodiversity VCs: those suitable for quantifying effects on vegetation communities, and those suitable for quantifying effects on wildlife. Changes in these measurement indicators were used to evaluate potential changes in the status of each VC relative to the assessment endpoints. Each measurement indicator was assessed quantitatively where sufficient information existed to support a numerical assessment, and qualitatively where necessary.

Ecosystem availability, ecosystem distribution, and ecosystem condition were selected as the measurement indicators for the vegetation communities VC. The measurement indicators are defined as follows:

- **Ecosystem availability**: changes to the amount (e.g., hectares) of vegetation communities.
- **Ecosystem distribution**: changes in the way each vegetation community is distributed on the landscape. Ecosystem availability and distribution are linked, but distribution focuses on the spatial configuration (or arrangement) and connectivity of ecosystems, whereas availability focuses on the amount of those ecosystems.
- **Ecosystem condition**: changes in species richness, species abundance and species diversity. Ecosystem condition is primarily affected by changes to structural stage and changes in the amount of moisture, amount of sunlight, competition with invasive species, dust deposition and contamination (e.g., radiological).

Habitat availability, habitat distribution, and survival and reproduction were selected as the measurement indicators for the terrestrial biodiversity species VCs. The measurement indicators are defined as follows:

- **Habitat availability**: changes to the amount (e.g., hectares) and quality (e.g., probability of use by animals) of different habitats.
- **Habitat distribution**: changes to spatial configuration and connectivity of habitats and changes to the spatial distribution and movement of animals.
- **Survival and reproduction**: changes to abundance caused by altering mortality or recruitment rates.

5.6.3 Assessment Boundaries

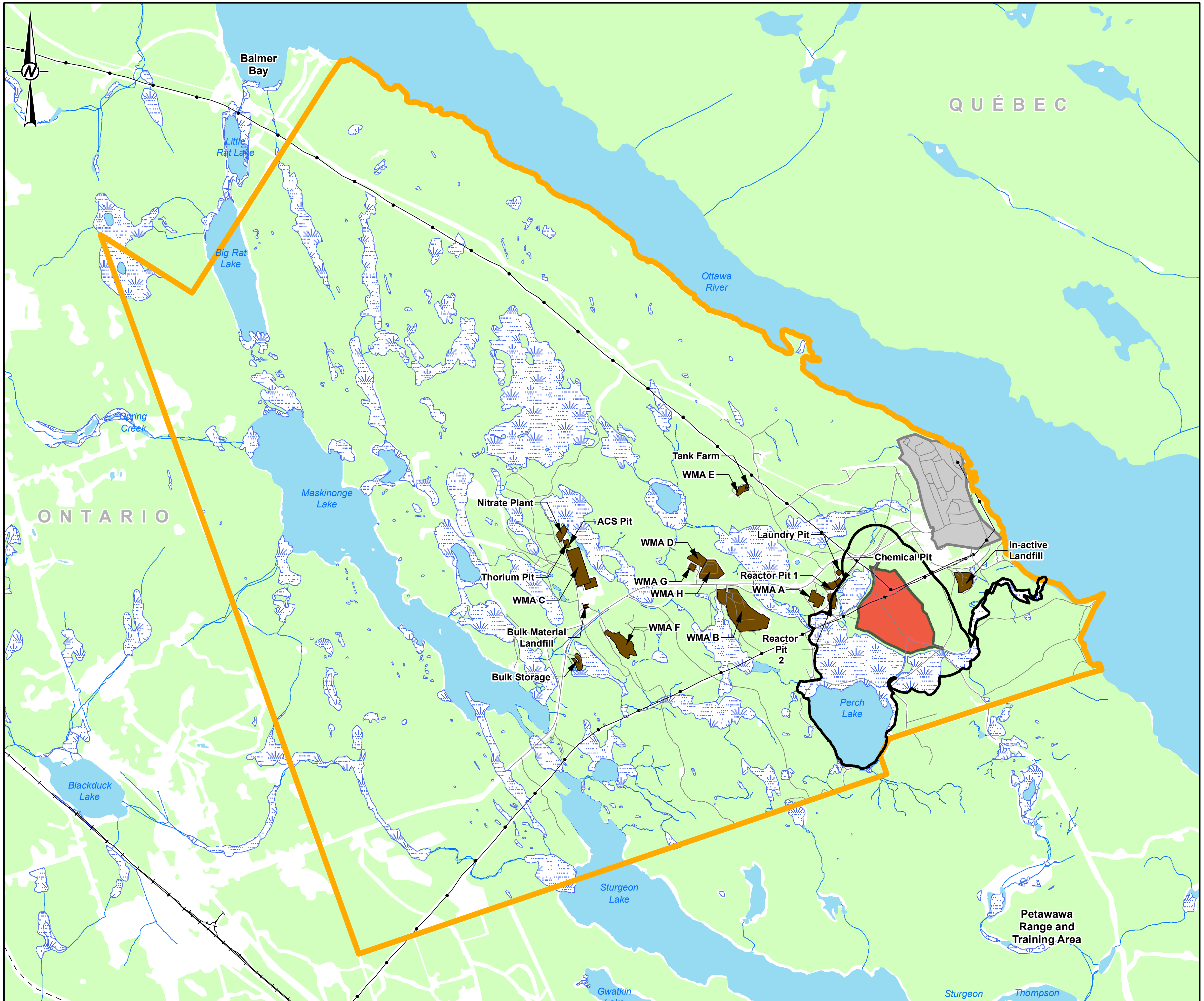
5.6.3.1 Spatial Boundaries

The spatial boundaries selected for the terrestrial biodiversity assessment were chosen because they permit description of existing conditions in sufficient detail to enable potential project-VC interactions and effects to be identified, understood, and assessed, including understanding and assessing the contribution of the NSDF Project to cumulative effects. The spatial boundaries selected for the terrestrial biodiversity assessment are presented on Figure 5.6.3-1 and are described below:

- **Site Study Area**: The SSA is the NSDF Project footprint, which accounts for the direct physical disturbance and alteration of vegetation communities and wildlife habitat caused by construction and operations of the engineered containment mound (ECM) and related facilities, buildings, and infrastructure. It also includes the two sections of East Mattawa Road that will be upgraded and form the north and south access roads to the ECM. The inclusion of these access road segments was made for terrestrial biodiversity because of the sensitivity of one VC species (Blanding's turtle) to road mortality. The SSA for terrestrial biodiversity encompasses 34 hectares (ha) (Figure 5.6.3-1).
- **Local Study Area**: The LSA includes the SSA plus any surface waterbody (i.e., Perch Lake and Perch Creek) that was a potential discharge point for wastewater from the ECM. A 250 metre (m) buffer was applied to the SSA to capture effects from the NSDF Project that may extend beyond the footprint, including those caused by emissions of dust and sensory disturbance caused by noise and light (Figure 5.6.3-1). Any wetland feature that intersected the 250 m buffer area was included in the LSA to capture potential effects on Blanding's turtle. The resulting LSA encompasses 203 ha.
- **Regional Study Area**: The RSA for terrestrial biodiversity is the CRL property boundary (Figure 5.6.3-1). This federally-owned property is within the larger Ottawa Valley Forest Management Unit and comprises one of three parcels of federal lands within the unit (Van Dyke 2011). The RSA is 3,853 ha and, because it contains the CNL nuclear facilities, it is managed differently from the surrounding landscape, which is provincial crown land, or private land. The RSA was used as the scale at which cumulative effects to terrestrial biodiversity VCs were assessed. Beyond regional disturbance factors (e.g., forestry and climate change) were considered if they were likely to affect vegetation communities or populations of wildlife VCs that overlap with the RSA.

This page left intentionally blank

232 509220 REPT 004
UNRESTRICTED



LEGEND

- ROADS
- RAILWAY
- HYDRO LINE
- NATURAL GAS PIPELINE
- RIVER/STREAM
- WATERBODY
- WETLAND
- WOODED AREA
- CRL MAIN CAMPUS
- WASTE MANAGEMENT AREA (WMA)[1]
- SIT STUDY AREA (NSDF PROJECT SITE)
- LOCAL STUDY AREA
- REGIONAL STUDY AREA (CRL PROPERTY)

1 0 1
1:35,000 KILOMETERS

NOTE(S)
1. LIQUID DISPOSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.

REFERENCE(S)
1. BASEDATA ONTARIO MNRF 2016, CANVEC 2016, AND CNL 2016
2. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
3. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE18N

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
TERRESTRIAL ENVIRONMENT STUDY AREAS

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	LH
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.6.3-1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:
25mm

This page left intentionally blank

5.6.3.2 Temporal Boundaries

Temporal boundaries (i.e., project phases) establish the timeframe during which NSDF Project effects are assessed. The temporal boundary represents the timeframe during which NSDF Project activities are actively occurring, and does not include the duration of predicted residual effects. The duration of an effect is defined as the amount of time between the start and end of a Project activity or stressor (which is related to the project phases) plus the time required for the residual effect to be reversed. In some cases, a residual effect may be irreversible within the temporal boundaries of the project (e.g., residual effect lasts for thousands of years). The following phases were identified for the NSDF Project:

- **Construction Phase:** includes site preparation and all activities associated with the construction of the NSDF. This phase includes activities such as installing the necessary supporting and/or ancillary facilities and NSDF infrastructure to facilitate NSDF operations, inactive commissioning and systems testing, and transportation of construction materials. Construction activities are expected take place from 2018 to 2020.
- **Operations Phase:** includes all activities associated with the waste receipt, waste placement, water management, wastewater treatment plant operations, vehicle movements into and from the NSDF Project site, and maintenance activities. The operations phase is expected to last approximately 50 years (i.e., 2020 to 2070).
- **Closure Phase:** includes activities necessary to complete the installation of the final cover and implementation of long-term monitoring. Closure activities are expected to start in 2070 and continue through to 2100, after which the NSDF Project will transfer into the post-closure phase.
- **Post-closure Phase:** has two discrete periods: Institutional Control and post-Institutional Control. The Institutional Control period includes implementation of both active and passive control throughout 2100 to 2400 (i.e., 300 years). During Institutional Control, groundwater monitoring and groundwater quality management will continue to demonstrate compliance with the safety case assumptions. Post-institutional Control occurs after year 2400 and continues indefinitely.

The temporal boundaries for the terrestrial biodiversity assessment includes consideration of effects for all NSDF Project phases, from construction through to post-closure.

5.6.3.3 Assessment Cases

The assessment cases considered in the terrestrial biodiversity assessment include the Base Case and the Application Case. Rationale for not considering a Reasonably Foreseeable Development (RFD) Case is provided.

- **Base Case** – This scenario represents existing conditions and characterizes effects from previous and existing developments and activities. The Base Case reflects the effects of existing disturbances in the area, such as forestry, transportation, agricultural, mining, and residential and recreational development. For example, current effects from the existing operations and activities on the CRL property are considered part of the Base Case.
- **Application Case** – This scenario represents the effects of the Base Case combined with the predicted incremental effects from the NSDF Project through all project phases for each VC.

- **Reasonably Foreseeable Development (RFD) Case** – This scenario represents the effects of the Base Case combined with the predicted incremental effects from the NSDF Project through all project phases, as well as effects from other RFDs in the RSA. Beyond regional disturbance factors (e.g., climate change) are also typically considered in the RFD Case as part of the cumulative effects assessment. There are no RFDs expected in the CRL property (i.e., the RSA) with the exception of new/upgrades to research and development facilities, new support infrastructure, and ongoing decommissioning and environmental restoration activities. New support infrastructure and research and development facilities will be located within existing disturbed areas on the CRL property (i.e., no disturbance to Greenfield areas). As such, potential effects from these activities are not expected to spatially overlap with potential effects to terrestrial biodiversity from the NSDF Project. The end-state plan for the CRL site will be to return lands disturbed by site activities to a condition that is physically stable, and safe in keeping with the land use and landscape of the day. Therefore, decommissioning and environmental restoration activities are anticipated to positively affect terrestrial biodiversity. Once existing infrastructure is removed and the CNL site is reclaimed and ceases to be frequented by large numbers of employees, the level of anthropogenic disturbance within the site will be greatly reduced, benefiting terrestrial biodiversity in the RSA. Because RFDs will either have no spatial overlap or are likely to positively affect terrestrial biodiversity), an RFD Case is not presented as part of this assessment.

5.6.4 Description of the Environment

The RSA is located in the Ontario Shield Ecozone and Georgian Bay Ecoregion 5E. This ecoregion has predominantly mixed forests characterized by a blend of northern and southern species, representative of the Great Lakes – St. Lawrence Forest Region (OMNR 2007). Lakes and rivers comprise over 10% of the surface area with wetlands relatively rare, only covering 2.5% of this ecoregion. Characteristic tree species of Ecoregion 5E include conifers such as eastern white pine, red pine (*P. resinosa*), eastern hemlock (*Tsuga canadensis*), and black spruce (*P. mariana*), and deciduous species such as yellow birch (*Betula alleghaniensis*), and sugar maple (*Acer saccharum*) (OMNR 2007). The natural disturbance regime in this region is a combination of fire, wind and insect damage (OMNR 2010a). Wildlife are diverse and abundant and characteristic regional species include eastern wolf (*Canis lupus lycaon*), American black bear (*Ursus americanus*), moose (*Alces americanus*), beaver (*Castor canadensis*), painted turtle (*Chrysemys picta*), common loon (*Gavia immer*), common raven (*Corvus corax*), and ruffed grouse (*Bonasa umbellus*) (OMNR 2007).

Specific details about the terrestrial biodiversity present within the RSA and LSA are presented in annual monitoring reports produced by CNL (AECL 2013a, 2014b; CNL 2015a, 2016a, 2016b) and reports prepared by consultants (CH2M Gore & Storrie Ltd. 1997, 1998; North-South Environmental Inc. 2002; Ecometrix 2013). These reports constitute the broader information about terrestrial biodiversity, including species of conservation concern, which is presented in Appendix 5.6-1 and was used to generate the list of terrestrial biodiversity VCs included in this assessment. The selected VCs are intended to focus the terrestrial biodiversity assessment, and this section therefore, focuses on describing the environment in 2016 (i.e., existing conditions) for each terrestrial biodiversity VC in the SSA, LSA, and RSA.

Existing conditions for each VC represent the outcome of past and present effects on the environment. The level of effect within the SSA, LSA, and RSA has varied over time. Although human occupation along the Ottawa River has been recorded from 4,000 to 5,000 years ago, the RSA was not affected by substantial industrial activity until the 1850s (AECL 2008). Fire was the primary disturbance factor in the RSA before the 1850s, although some selective logging for eastern white pine occurred in the RSA during the early 1800s.

The Mattawa Road opened as a winter road in 1854, permitting greater access into the RSA. Farmsteads were established in 1857 and the land was cleared of forests in many places (AECL 2014a). These small farms comprised most of the land use in the RSA until the federal government expropriated the land for construction of CRL in 1944 (AECL 2014a). Since the 1940s, land uses in the RSA have been limited to operations and activities undertaken at the CRL main campus and associated facilities (AECL 2008, 2010). Vegetation clearing has been limited and the majority of the property has been undisturbed since the 1940s (i.e., for approximately 75 years), with the result that forests greater than 75 years old are common.

Forest fires in the RSA have been limited, although several serious fires have occurred on the adjacent Canadian Forces Base Petawawa (AECL 2013b). Current fire suppression activities are regularly undertaken in the RSA because fire poses a safety hazard to the nuclear facilities at the CRL property (AECL 2008). The result is that the RSA currently serves as a refugium for vegetation communities and wildlife species associated with mature forests, including a number of species at risk.

Anthropogenic disturbance of the RSA and current activity (e.g., the CRL main campus area, access roads, firebreaks, and waste management areas) is largely concentrated in the southeast corner of the RSA. Disturbance in the form of roads is also primarily within the southern third of the property, with the main access road for employees (Plant Road) running east-west, with numerous secondary roads branching off the main Plant Road to specific destinations (i.e., Dump Road, Foundation Road, Area B Road, Laundry Pit Loop, Power Line Road, Perch Lake Ring Road). There are two cleared and maintained hydroelectric corridors for the 115 kilovolt (KV) transmission lines through the CRL property; one spanning most of the north-south length of the property and the other spanning the southern east-west length of the property.

Overall, CNL's activities in the RSA have likely improved conditions for terrestrial biodiversity relative to conditions present in the 1940s (i.e., when much of the land was being cleared for agricultural use). Consequently, much of the RSA maintains high value for terrestrial biodiversity, including the VCs identified for this assessment. Within this context, and in cases where data were limited for some VCs, existing conditions were estimated using precautionary assumptions. For example, where suitable habitat was present for a VC was present, the VC was assumed to use the habitat, unless substantial survey effort was available to demonstrate that the VC was absent. The following information sources were used to describe existing conditions for terrestrial biodiversity VCs:

- reconnaissance-level walk-through of the SSA by senior Golder biologist conducted on June 30, 2016;
- results of fieldwork undertaken by CNL staff in the LSA during 2012, 2013 and 2016, including forest songbird surveys (5 acoustic recorders, 750 minutes of audio recording analyzed), amphibian surveys (7 acoustic recorders, 336 minutes of recording analyzed), wetland bird surveys (2 acoustic recorders, 200 minutes of recording analyzed), and bat surveys (3 acoustic recorders, 128 minutes of recording analyzed);
- studies published in scientific journals and reports;
- previous environmental assessments and terrestrial biodiversity surveys conducted within the RSA;

- federal recovery strategies for VCs available in Environment and Climate Change Canada's (ECCC) Species at Risk database (Government of Canada 2016);
- Forest Management Plan for the Ottawa Valley Forest (Van Dyke 2011);
- Forest Management Guide for Great Lakes – St. Lawrence Landscapes (OMNR 2010a);
- Forest Resource Inventory (FRI) GIS spatial data (original source from Gendron Resource Surveys 1987);
- wetland GIS spatial data (received from CNL May 2016);
- road GIS spatial data (two datasets used and merged: received from CNL May 2016 and downloaded from the Land Information Ontario (LIO) data warehouse (OMNRF 2016a); and
- Ontario Ministry of Natural Resources and Forestry (OMNRF) Natural Heritage Information Centre Make-a-Map: Natural Heritage Areas (OMNRF 2016b).

A description of the existing conditions based on these information sources is provided for each terrestrial biodiversity VC in the following sections. Existing conditions are described according to the measurement indicators selected for each VC (refer to section 5.6.2.1). Existing conditions for vegetation communities are described first because the maps generated to describe ecosystem availability and distribution for that VC are then used to describe habitat conditions for each species level VC.

For each wildlife VC, habitat mapping based on ecosystem data was used to provide spatially explicit descriptions of habitat availability and distribution under existing conditions, representing an estimate of suitable habitat available as a result of past and present development and activities. A review of habitat requirements and species ecology was completed for each wildlife VC to identify habitat that is most likely to be limiting for the species in the RSA and the loss of which would be most likely to result in change to its abundance in the RSA. The limiting habitat was selected as the focus of the assessment.

5.6.4.1 Vegetation Communities

5.6.4.1.1 Ecosystem Availability

Ecosystem availability was described using available FRI data. Vegetation communities are typically classified in central and southern Ontario using the Ecological Land Classification (ELC) system; however, classification of "ecosite," a descriptive unit under the ELC system, is not included in the FRI spatial data available for the RSA. According to the Forest Management Plan for the Ottawa Valley Forest, ecosite descriptions have not been developed for any of the federally-owned lands within the Ottawa Valley Forest Management Unit (Van Dyke 2011).

The FRI dataset available for the RSA consists of spatially explicit polygons that provide information on forest tree species composition, as well as other non-forested categories of land cover. The FRI data are typically derived by aerial photo interpretation with varying degrees of ground-truthing, depending on the age of the dataset; it is believed the FRI dataset for the RSA is based on mapping work conducted in 1987; however, the dates associated with polygon delineation were not provided with the dataset. Forest cover information from the FRI dataset that was used for this assessment included: forest unit (described below), forest tree species composition (as two-letter species codes), polygon / stand area (in hectares), and age (in years). It should be noted these data are intended to be used by forest managers to guide forestry activity, not specifically for assigning habitat classification.

Forest units are categories of forest stands within the larger Forest Management Unit (i.e., the Ottawa Valley Forest in this case). These units have similar species composition, similar successional trends (from natural and/or silvicultural disturbance), and are managed under the same silvicultural system (Van Dyke 2011). For the purposes of defining vegetation community types that are useful for classifying ecosystems and wildlife habitat value, the following categories were derived from FRI data:

- **Mixed forest** – Forest stands containing deciduous and coniferous trees in upper canopy. The mixed forest communities identified that occur within the RSA include: red oak (*Quercus rubra*) – eastern white pine (*Pinus strobus*) forest. Dominant tree species in mixed stands surveyed as part of the North-South Environmental survey work in 2002 were recorded as red maple (*Acer rubrum*), poplar (i.e., aspen sp. [*Populus* sp.]) and eastern white pine. Woody debris and snags (i.e., standing dead trees, with high wildlife nesting value) were reported as abundant in mixed and deciduous forest types. Dominant shrub layer species recorded in both mixed and deciduous forests included striped maple (*A. pensylvanicum*), mountain maple (*A. spicatum*), immature sugar maple (*Acer saccharum*) and red maple, birch (*Betula* sp.), balsam fir (*Abies balsamea*), eastern white pine, maple-leaved viburnum (*Viburnum acerifolium*), beaked hazelnut (*Corylus cornuta*), round-leaved dogwood (*Cornus rugosa*), and eastern leatherwood (*Dirca palustris*). Herbaceous species dominant in the understory include wild sarsaparilla (*Aralia nudicaulis*), large-leaved aster (*Eurybia macrophylla*), spinulose wood fern (*Dryopteris carthusiana*), northeastern lady fern (*Athyrium filix-femina* var. *angustum*), wild lily-of-the-valley (*Maianthemum canadense* ssp. *canadense*), eastern teaberry (*Gaultheria procumbens*), and late lowbush blueberry (*Vaccinium angustifolium*).
- **Deciduous forest** – Forest stands containing only deciduous trees in upper canopy. The deciduous forest communities identified that occur within the RSA include: sugar maple – large-toothed aspen (*Populus grandidentata*) forest, poplar – red maple forest with deciduous understory, and poplar – red maple – oak (*Quercus* sp.) forest. Dominant shrub layer species in these forests similar to those in the mixed forests. Dominant tree species in deciduous stands surveyed as part of the North-South Environmental survey work in 2002 were recorded as red maple and poplar. Along Mattawa Road, forests containing maple and beech (*Fagus* sp.) that considered to have more southern Great Lakes influence, are more common. Woody debris and snags were reported as abundant in mixed and deciduous forest types.
- **Coniferous forest** – Forest stands containing only coniferous trees in upper canopy. The North-South Environmental survey work in 2002 classified the forested area within the north portion of the SSA, north of the east-west transmission line right-of-way (ROW), and straddling the north-south transmission line ROW, as white pine / red pine (*Pinus resinosa*) forest. This community was characterized as having 20-40 centimetre (cm) diameter at breast height (dbh) red pine and/or white pine in a closed canopy. White pine is sub-dominant, followed by red maple and less commonly white birch (*Betula papyrifera*), white spruce (*Picea glauca*) and red oak. The tall shrub layer was determined to be very sparse in areas and consists of immature white pine, beaked hazelnut, striped maple and immature balsam fir. The herbaceous layer is dominated by eastern teaberry, wild sarsaparilla, late lowbush blueberry, white-grained mountain-ricegrass (*Oryzopsis asperifolia*), large-leaved aster, and bracken fern (*Pteridium aquilinum*). Rock outcrops and woody debris were both noted to be common.

- **Wetlands** – Primarily marsh and swamp type wetlands (with some bog and fen type) as determined through FRI and CNL wetland mapping based on surveys conducted by CH2M Gore & Storrie (1997 and 1998). Wetlands are highly important wildlife habitat features and can be very sensitive to physical disturbances or changes to hydrological processes, depending on wetland type. For example, wetlands with plant species that are sensitive to nutrient enrichment and can be out-competed by other more common species if nutrient levels are altered (Granger et al. 2005). Within the RSA, wetlands provide important habitat for bat foraging and maternity roosting (if mature treed swamps) and Blanding's turtle hibernation, mating, foraging, thermoregulation, staging prior to nesting and for movement.
- **Flooded Areas** – Saturated areas not included under the classification of wetlands or aquatic habitat that were mapped in the FRI dataset. This includes areas originally mapped and coded as FL (flooded), M1 (lowlands – emergent vegetation), M2 (lowlands – sedges, grasses) and M3 (lowlands – shrubs, herbs, sedges). They constitute a minor component of the RSA (0.8 ha or <1%).
- **Unclassified (cleared) –** An FRI designation for non-forested areas created for uses other than timber production, including roads, hydroelectric corridors or any anthropogenically altered area cleared of trees; OMNR 2009). The North South 2002 survey report provides information on the composition of the vegetation community within the hydroelectric corridors in the RSA. The dominant species are primarily herbaceous, as the rights of way must be operationally maintained at low vegetation height. Species recorded include the following native plants: sweet fern (*Comptonia peregrina*), bracken fern, spreading dogbane (*Apocynum androsaemifolium*), field horsetail (*Equisetum arvense*), and heart leaved aster (*Symphyotrichum cordifolium*). On steep slopes where there is bare ground and sparse vegetation cover, there are patches of exposed sand that were described as reminiscent of sand barrens, a significant vegetation community in Ontario; however, their small size and lack of provincially significant species occurrence precludes them from being designated as such. In these steep, exposed sandy areas, dominant species recorded include dry spike sedge (*Carex siccata*) and common scouring rush (*E. hyemale*).

The classification of forest stand types (mixed, deciduous and coniferous) was conducted using the composition of deciduous and/or coniferous tree species within each FRI polygon and assigning it as either "mixed," "deciduous," or "coniferous". If a stand had both coniferous and deciduous tree species present based on the assessment conducted as part of FRI mapping, it was classified as "mixed", if a stand had only deciduous or coniferous tree species present, it was classified as such. The FRI codes for Forest Unit could not be used because each Forest Unit can consist of more than one forest type. For example, a single forest unit, such as Mixed Uniform Shelterwood, can contain mixed, coniferous and deciduous forest stands. Consequently, Forest Unit was not used to define the forest stand type, although Forest Unit can inform species composition (Appendix 5.6-2). Other information associated with each forested vegetation community category, such as leading tree species and stand age, was used to identify the availability of suitable habitat for wildlife VCs (refer to Section 5.6.5.2 through Section 5.6.5.7).

Spatial data delineating the availability of wetlands within the terrestrial biodiversity study areas was provided by CNL and merged with the FRI dataset. Where CNL-derived wetland polygons overlapped FRI unclassified area polygons (i.e., roads, hydroelectric corridors), the unclassified area designation took priority, and the CNL wetland layer took priority otherwise. The CNL wetland layer was considered a better overall spatial representation of wetlands in the RSA, although the FRI data were considered a better representation of disturbance.

Although there are coniferous tree plantations within the RSA, and these were delineated by FRI mapping as separate FRI polygons, the species composition and inclusion of relatively old stand ages distinguish them from typical coniferous tree plantations in Ontario that are more heavily managed and frequently disturbed. For this reason, plantations are described and considered, but were not distinguished as a distinct vegetation community – they were considered as either coniferous or mixed forests (depending on recorded tree species composition). In addition to mapping using FRI data, a spatial query of the OMNRF Make-a-Map system for natural heritage areas was conducted to determine whether recorded and designated provincially significant natural features might be present within the RSA.

Availability of vegetation communities within the RSA and LSA under existing conditions are presented in Table 5.6.4-1. According to a spatial query of the OMNRF Make-a-Map system for natural heritage areas, there are no recorded and designated provincially significant natural features within the RSA (OMNRF 2016b). These would include designated provincially significant wetlands and areas of natural heritage and scientific interest.

Table 5.6.4-1: Availability of Vegetation Communities under Existing Conditions

Vegetation Community	Description	RSA		LSA	
		Area [ha]	Percent [%]	Area [ha]	Percent [%]
Mixed Forest	Forested areas with deciduous and coniferous tree composition	1,929.9	50.1	65.9	32.5
Deciduous Forest	Forested areas with only deciduous tree composition	642.6	16.7	4.8	2.4
Coniferous Forest	Forested areas with only coniferous tree composition	199.4	5.2	4.7	2.3
Wetland	Marshes, swamps as determined through FRI and detailed survey and mapping (CH2M Gore & Storrie 1997, 1998)	521.7	13.5	60.7	29.9
Flooded Area	This includes areas originally mapped and coded as FL (flooded), M1 (lowlands – emergent vegetation), M2 (lowlands – sedges, grasses) and M3 (lowlands – shrubs, herbs, sedges)	0.8	0	0	0
Unclassified (Cleared)	Based on FRI data, indistinguishable between hydroelectric corridor, road surface, buildings; includes all anthropogenically-altered ground surfaces	268.3	7.0	26.1	12.9
Aquatic Habitat (lakes, streams):		273.6	7.1	40.7	20.0
Slivers / Gaps (GIS gaps in spatial data coverage):		16.4	0.4	0	0
	Total:	**3,852.7**	**100**	**202.8**	**100**

The RSA is primarily forested (72% of total area, including lake and stream features). Forests are predominantly mixedwood and deciduous, dominated by poplar species such as aspen, red maple, with stands of eastern white pine and spruce species (*Picea* spp.) in some places. The RSA contains a number of small lakes and streams (e.g., Maskinonge Lake, Clear Lake, Chalk Lake, Perch Lake, and Perch Creek), which make up 7% of the total area. Wetlands are also common, making up another 14% of the total RSA area. The remaining 7% contains “unclassified” (i.e., anthropogenically modified) areas, consisting of roads, two 115 KV hydroelectric corridors, waste management areas (WMAs), and all other developed areas such as the CRL Chalk River main campus area.

The LSA is located in the southeastern corner of the RSA, in a primarily undisturbed area adjacent to the most heavily anthropogenically altered areas in the RSA, including the CRL main campus and various WMAs. The LSA is a mix of forested (37%) vegetation communities and wetlands (30%). The proportion of wetlands in the LSA is relatively high compared to the rest of the RSA and surrounding region in general; reflecting how the LSA for terrestrial biodiversity was derived (see Section 5.6.3.1). Wetlands consist of South Swamp to the south of the SSA, East Swamp to the northwest of the SSA (that will receive Wastewater Treatment Plant [WWTP] discharge), and the marsh wetlands surrounding Perch Lake and Perch Creek. Aquatic habitat, largely comprised of Perch Lake and Perch Creek, covers 20% of the LSA. Anthropogenically altered (“unclassified”) areas in the form of roads, hydroelectric corridors, and one inactive liquid dispersal area (Reactor Pit 1) comprise the remaining 12.9% of LSA.

The SSA is 33.7 ha and consists primarily of second-growth, mature, mixed forest, dominated by poplar species, red oak, eastern white pine, and spruce species (71% of total SSA). It also contains a 1.2 kilometre (km)-long segment of East Mattawa Road, and two linear areas cleared as 30 to 45 m wide ROW for overhead hydroelectric lines. The East Mattawa Road corridor was not captured in the FRI data, but the hydroelectric corridors were, and they comprise 11% of the total SSA. Inclusion of the true extent of East Mattawa Road would result in a minor decrease to the mixed forest total coverage of the SSA, because it bisects a mixed forest stand.

There are two areas of immature coniferous forest stands comprising 12% of the total SSA: one is a tree research plantation containing 100% Norway spruce (*Picea abies*), and the other is a portion of a stand of spruce, balsam fir and larch species (*Larix* spp.). The Norway spruce research plantation is within the western portion of the SSA and was planted in the 1950s. Personnel with the Petawawa Research Forest have confirmed this plantation is no longer required for research purposes. There is also a portion of one deciduous forest stand, within the northwest end of the SSA, which contains poplar sp., yellow birch (*Betula alleghaniensis*) and red oak, and comprises 7% of the total SSA.

There are no wetlands, flooded areas, or aquatic habitat features within the SSA. The surficial geology around the SSA consists primarily of sands, underlain by dense sandy silt till containing cobbles and boulders. Organic soils (e.g., peat) have deposited in the low-lying areas. The overburden thickness at the site typically ranges from approximately 0 to 10 m, depending on bedrock topography. The vegetation communities present within the SSA reflect these soil conditions.

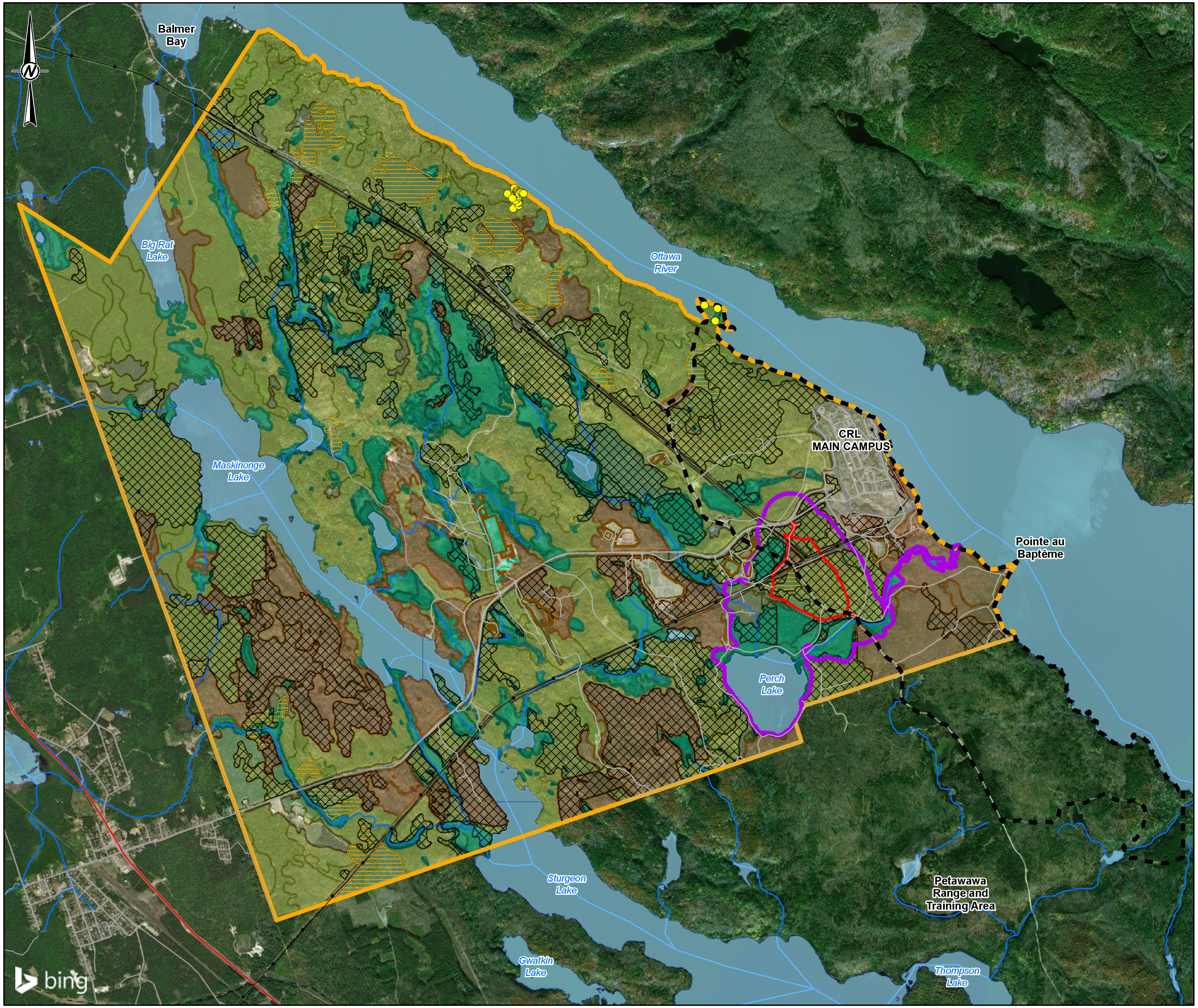
5.6.4.1.2 Ecosystem Distribution

Because the RSA has remained largely undisturbed since the 1940s, it consists primarily of natural vegetation communities distributed according to natural ecological patterns. Forested vegetation communities make up (72%), with a mosaic of forested areas interspersed with wetland areas and lakes that make up a combined 21% of the total area. The degree of anthropogenic disturbance is generally on a north to south gradient, with the most northern part of the RSA generally undisturbed (with the exception of a hydroelectric corridor), and the southern part of the RSA most disturbed, where the CRL main campus, main employee access road (Plant Road) and other secondary access roads, as well as other WMAs are located. Anthropogenically altered ("unclassified") areas of the RSA comprise a total of 7% of the total area. Distribution of vegetation communities within the RSA in the Base Case are presented in Figure 5.6.4-1.

Distribution of vegetation communities within the LSA and SSA in the Base Case are presented in Figure 5.6.4-2. By virtue of how the LSA was derived, there are swamp and marsh-type wetlands surrounding the perimeter of the LSA on the south (Perch Lake Swamp, Perch Lake Fringe, Outlet Swamp), west (South Swamp, East Swamp), and east sides (Outlet Swamp surrounding Perch Creek). The remaining portion of the LSA is forested with poplar, red oak, and eastern white pine dominated stands that are partially fragmented by 13% coverage of unclassified (anthropogenically cleared) areas. These altered areas are primarily made up of Plant Road and the two hydroelectric corridors, as well as a portion of the cleared area surrounding Reactor Pit #2. Plant Road and the hydroelectric corridors are linear features that bisect natural forested ecosystems across the LSA boundaries. East Mattawa Road is another linear feature on the landscape that exists, but was not captured by FRI mapping (i.e., so is not included in the calculated coverage of unclassified areas). There is also one isolated stand of Norway spruce (i.e., research plantation) within the LSA that is within a larger stand of poplar and red-oak dominated forest.

This page intentionally left blank

232 509220 REPT 004
UNRESTRICTED



LEGEND

- HIGHWAY
- ROAD
- TRANSMISSION LINE
- NATURAL GAS PIPELINE
- RIVER/STREAM
- WATERBODY
- CRL MAIN CAMPUS
- WASTE MANAGEMENT AREA (WMA)[1]
- REGIONAL STUDY AREA (CRL PROPERTY)
- LOCAL STUDY AREA
- SITE STUDY AREA (NSDF PROJECT SITE)
- NORTH-SOUTH 2002 STUDY AREA

VEGETATION COMMUNITIES

- MIXED FOREST
- DECIDUOUS FOREST
- CONIFEROUS FOREST
- WETLANDS
- FLOODED AREA
- UNCLASSIFIED (CLEARED)
- MATURE FOREST STAND
- PLANTATION

SARA LISTED PLANT SPECIES OBSERVATION

- BUTTERNUT OBSERVATION

1 0 1

1:35,000 KILOMETRES

NOTE(S)

1. LIQUID DISPOSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.

REFERENCE(S)

1. BASEDATA MNRF 2016 AND CANVEC 2016
2. IMAGERY: © 2017 DIGITALGLOBE IMAGE COURTESY OF USGS EARTHSTAR GEOGRAPHICS SIO © 2017 MICROSOFT CORPORATION
3. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE18N

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
VEGETATION COMMUNITIES AVAILABILITY AND DISTRIBUTION IN THE RSA – BASE CASE

CONSULTANT
Golder Associates

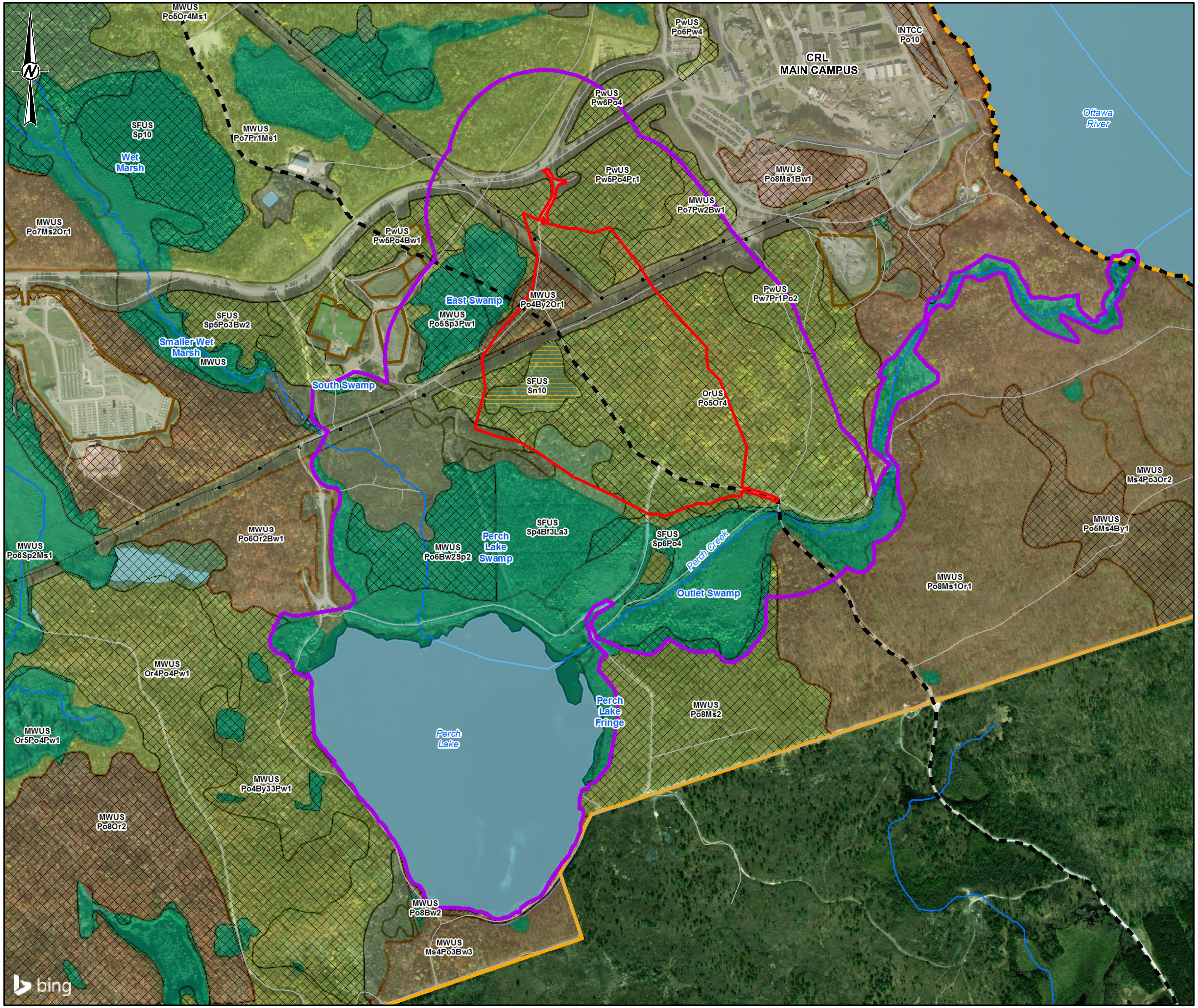
YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	LH
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.6.4-1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:
25mm

S:\Clients\Canadian_Nuclear_Laboratories\NSDF\99_PROJ\1547525_NSDF_EIS\40_PROD\0009_EIS_Section_5\Section_5.6_Terrestrial\1547525-0009-RT-0002.mxd

This page left intentionally blank



LEGEND

- HIGHWAY
- ROAD
- TRANSMISSION LINE
- RIVER/STREAM
- WATERBODY
- CRL MAIN CAMPUS
- WASTE MANAGEMENT AREA (WMA)[1]
- REGIONAL STUDY AREA (CRL PROPERTY)
- LOCAL STUDY AREA
- SITE STUDY AREA (NSDF PROJECT SITE)
- NORTH-SOUTH 2002 STUDY AREA

VEGETATION COMMUNITIES

- MIXED FOREST
- DECIDUOUS FOREST
- CONIFEROUS FOREST
- WETLANDS
- FLOODED AREA
- UNCLASSIFIED (CLEARED)
- MATURE FOREST STAND
- PLANTATION

FOREST UNIT CODES:

Forest Unit	Description
MWUS	Mixed Uniform Shelterwood
PWUS	White Pine Uniform Shelterwood
SFUS	Spruce - Fir Uniform Shelterwood
INTCC	Intolerants Clear Cut
ORUS	Red Oak

FOREST COVER SPECIES CODES:

FRI Code	Tree Species	Coniferous (C) or Deciduous Species (D)
Bf	Balsam Fir (Abies balsamea)	C
Bw	Dwarf White Birch (Betula minor) or Paper Birch (B. papyrifera)	D
By	Yellow Birch (B. alleghaniensis)	D
La	American Larch (Tamarack) (Larix laricina)	C
Ms	Red Maple (Soft Maple) (Acer rubrum)	D
Or	Northern Red Oak (Quercus rubra)	D
Po	Poplar species (Populus sp.)	D
Pr	Red Pine (Picea resinosa)	C
Pw	Eastern White Pine (Pinus strobus)	C
Sp	Spruce species (Picea sp.)	C

250 0 250

1:10,000 METRES

NOTE(S)

1. LIQUID DISPOSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.

REFERENCE(S)

1. BASEDATA MNRF 2016 AND CANVEC 2016
2. IMAGERY: © 2010 DIGITALGLOBE IMAGE COURTESY OF USGS EARTHSTAR GEOGRAPHICS SIO © 2017 MICROSOFT CORPORATION
3. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE18N

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
VEGETATION COMMUNITIES AVAILABILITY AND DISTRIBUTION IN THE LSA AND SSA – BASE CASE

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	LH
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.6.4-2

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:
25mm
0

This page left intentionally blank

5.6.4.1.3 Ecosystem Condition

The classification of structural classes for each FRI Forest Unit were used to determine the seral stage of each forested polygon within the RSA as a measure of ecosystem condition. Structural class for each polygon were obtained using the Forest Management Plan for the Ottawa Valley Forest (Van Dyke 2011) and the Forest Management Guide for Great Lakes-St. Lawrence Landscapes (OMNR 2010a). In cases where the two sources had different structural class assigned to the same polygon, the youngest age ranges were considered “mature” to provide a conservative assessment of the potential for the NSDF Project to affect mature forest stands. The ages for each seral stage specific to each forest unit are provided in Appendix 5.6-2.

Age classes for each forested vegetation community are defined as follows:

- **Pre-sapling**: Very young forest created by stand-replacing natural disturbance, clear-cut harvest or final removal shelterwood harvest where the remaining stand is very young (Van Dyke 2011).
- **Sapling**: General term for young trees beyond seedling but not yet at pole stage, at vigorous growth stage and consists of trees without dead bark and only occasional dead branches (NRCan 2016).
- **Immature**: Definition as it relates to forest management; in even-aged management this refers to stands of trees past regeneration stage, but not yet mature; and in uneven-aged management refers to established trees too young for commercial harvest (NRCan 2016).
- **Mature**: Definition as it relates to forest management; in even-aged management this refers to stands of trees sufficiently developed to be harvestable and are at or near rotation age (NRCan 2016).
- **Old growth**: Distinguishable from younger stands based on the structure, ecological function and species composition. There is an accumulation of woody debris and the presence of species and functional processes representative of the potential climax natural community (in the absence of disturbance; NRCan 2016). The age of onset varies based on dominant tree species, for example, poplar trees are relatively short-lived compared to other tree species. As a result, poplar-dominated forests are considered old growth at 95 years and red pine-dominated forests are considered old growth at 140 years (Watkins 2011).

Additional description of ecosystem condition was qualitative and relied upon information contained in previous studies conducted within the RSA about radiological contamination, abundance and distribution of native and non-native plant species, and the presence of any significant ecosystem communities (i.e., sand barrens or provincially significant wetlands).

The relative composition of forest structural stages within the forested areas of the RSA and LSA provides a measure of ecosystem condition. Older aged forest stands are considered higher quality, as they provide greater habitat complexity and have higher species diversity. Structural stages of forested vegetation communities are summarized below in Table 5.6.4-2.

The forest type and structural age class with the largest spatial coverage within the RSA is immature mixed forest (32%). Considering all forest types combined, immature forest comprises 42% of the total RSA. Mature mixed forest is the second largest forest type and structural age class by area coverage in the RSA (17.8%), and when considering all forest types combined, mature forest is also the second largest structural stage (27.8%). Pre-sapling and sapling forest areas are relatively minor on the RSA landscape (combined for all forest types only comprising 2.2%). This is not surprising given the restricted activity and forest fire suppression within the CRL property. There are no old forest stands in the RSA.

Within the LSA, there is a relatively older assemblage of forest stands compared to the RSA, with 30.9% spatial coverage of all combined forest types in the mature age class. The LSA has no pre-sapling, sapling or old stands, all are either immature or mature. Compared to the RSA as a whole, the LSA has a higher quality of forest assemblages, as they are primarily mature, and therefore provide high-quality habitat for mature-forest dependant species, including those that depend on cavities and other features associated with wildlife trees.

Table 5.6.4-2: Structural Stages of Forested Vegetation Communities in the RSA and LSA by Forest Type (Base Case)

Forest Type	Structural Stage Category	RSA		LSA	
		Area [ha]	Percent[(a)] [%]	Area [ha]	Percent [%]
Mixed	Pre-sapling	4.2	0.1	0	0
	Sapling	9.2	0.2	0	0
	Immature	1,232.2	32.0	6.1	3.0
	Mature	684.2	17.8	59.8	29.5
	Old	0	0	0	0
Deciduous	Pre-sapling	25.1	0.7	0	0
	Sapling	30.1	0.8	0	0
	Immature	288.6	7.5	2	1.0
	Mature	298.8	7.8	2.8	1.4
	Old	0	0	0	0
Coniferous	Pre-sapling	1.6	0	0	0
	Sapling	13.5	0.4	0	0
	Immature	97.4	2.5	4.7	2.3
	Mature	86.9	2.3	0	0
	Old	0	0	0	0
Total – All Forest Types Combined	**Pre-sapling**	**30.9**	**0.8**	**0**	**0**
	Sapling	**52.8**	**1.4**	**0**	**0**
	Immature	**1,618.2**	**42.0**	**12.8**	**6.3**
	Mature	**1,069.9**	**27.8**	**62.6**	**30.9**
	Old	**0**	**0**	**0**	**0**

a) Percentages based on total area of the RSA and LSA, respectively, inclusive of all other land cover types, not just forest (i.e., wetlands, flooded areas, unclassified (cleared) areas, and aquatic habitat).

Considering the coverage of rare plants within the RSA, butternut (*Juglans cinerea*) is the only SARA-listed plant species that has been recorded in the RSA (see Figure 5.6.4-1). This species does not have a high likelihood of occurring within the SSA based on the location of the RSA, which is beyond the known northern extent of the range of butternut in Ontario, and site conditions. Surveys to-date have not indicated the presence of butternut within the SSA, and suitable habitat is not common in that location. Suitable butternut habitat consists of a range of tolerable soil types, but the highest quality conditions are rich, moist, well-drained loams typically within streamside riparian areas, and also well-drained gravely sites of limestone origin (Environment Canada 2010). Butternut is shade intolerant, but can be a minor component of late-successional stage forests with openings in the canopy. Butternut within the RSA (but outside of the LSA) are associated with an old homestead. Some regeneration was noted in one patch during surveys, but it was always in close proximity to the parent trees that were associated with the old homestead.

As described in Section 5.3.4.4.2, the East Swamp wetland, which is adjacent to the SSA, has existing radioactive contamination associated with a shallow subsurface plume from the Chemical Pit, and a second plume from Reactor Pit #2. The surface contamination distribution in the East Swamp has been characterized with radiation field surveys, surface surveys, and vegetation contamination surveys performed in 2002, 2007 and 2012. In 2002 and 2012, these surveys included wetland soil and vegetation sampling to determine the radionuclide concentrations in these media. These results are discussed in Section 5.7.4.7 Radioactivity in Soils.

5.6.4.2 Migratory Birds

5.6.4.2.1 Habitat Availability

Given the large number of species of birds from various families that are classified as migratory birds, habitat preferences among migratory bird species are highly diverse and cover the range of available habitats in the RSA. A total of 117 migratory bird species are known to be present in the RSA or have the potential to be present in the RSA based on known distribution and presence of suitable habitat in the RSA (Appendix 5.6-3). Many of these are forest landbirds, but there are also a number of waterfowl and waterbirds.

The vegetation community data were used to map suitable habitat for migratory birds in the LSA and RSA. Migratory birds have the potential to occupy all natural habitat available in the RSA and, therefore, suitable habitat for migratory birds was evaluated as all age classes (if applicable) for all natural cover types. The potential exists for all of the natural cover types in the RSA and LSA to be occupied by various species of migratory birds at various times of the year (i.e., breeding season, during migration, winter).

Some migratory bird species will also occupy anthropogenic structures. This potential was considered qualitatively, but only natural cover types were considered in quantitative estimates of habitat availability for migratory birds. Table 5.6.4-3 presents habitat availability for migratory birds. Approximately 3,568 ha (92.6%) of the RSA and 177 ha (87.1%) of the LSA represent available habitat for migratory birds in the Base Case. The SSA comprises mostly mature mixed forest, but wetlands and aquatic habitat (Perch Lake) are also prominent habitat types in the LSA (Section 5.6.4.1.1).

Table 5.6.4-3: Habitat Availability for Migratory Birds (Base Case)

Habitat Suitability	Regional Study Area		Local Study Area	
	Area [ha]	Percent [%]	Area [ha]	Percent [%]
Suitable	3,568	92.6	177	87.1
Unsuitable	285	7.4	26	12.9
Total	3,853	100	203	100

ha = hectare; % = percent.

Disturbances (fire, anthropogenic) have likely had both positive and negative effects on migratory bird habitat availability at Base Case, depending on the habitat preferences of the species. For example, forest fire or logging may represent habitat loss for a forest species, but habitat gain for an edge or early-successional species. The development of industrial infrastructure in the RSA represents a loss of habitat for most species of migratory birds, but other disturbances (e.g., fire, logging, farmsteading) would have had mixed effects on habitat availability for migratory birds as a group, with some species benefiting from these disturbances, while others experienced habitat loss.

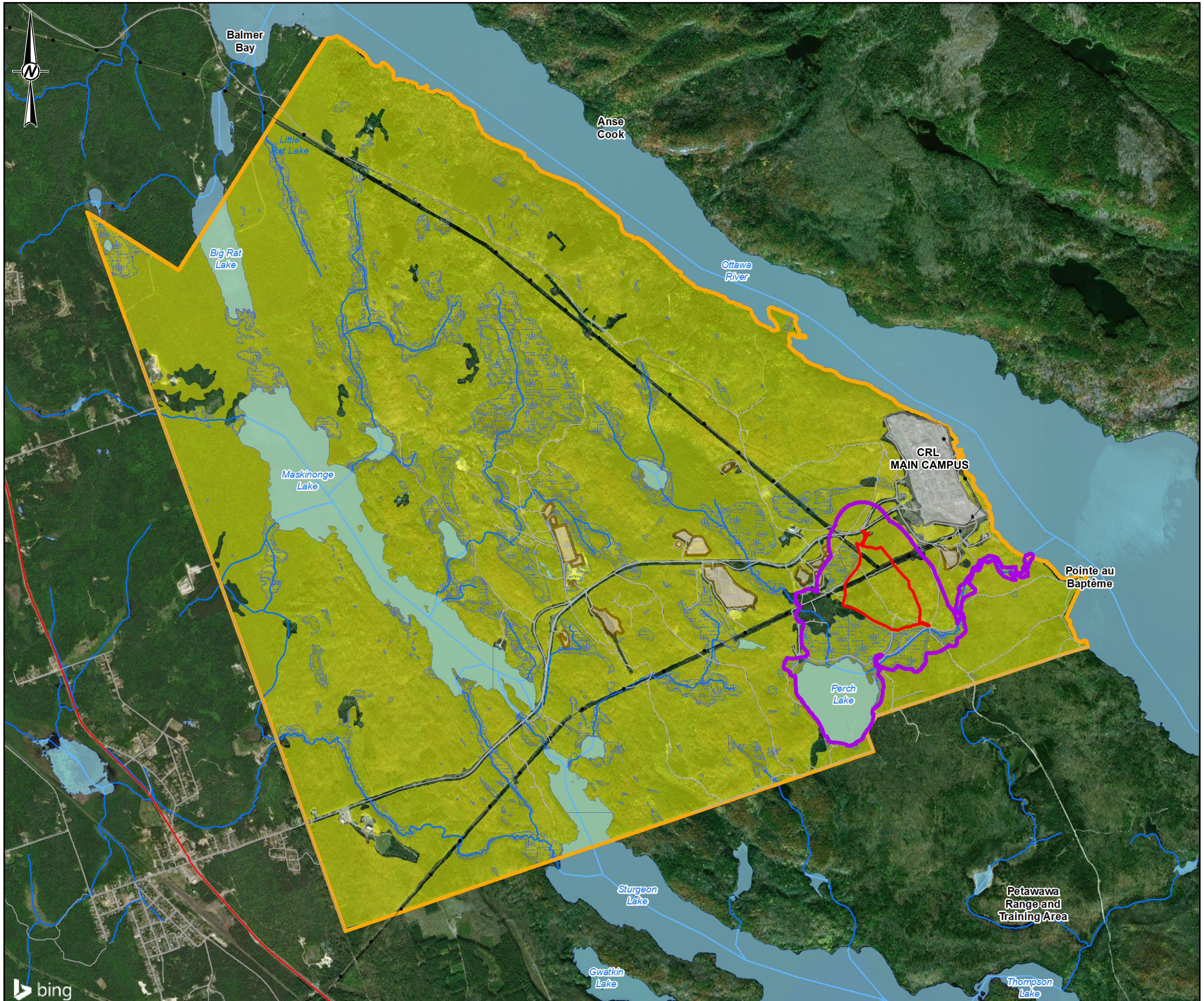
Several forms of significant wildlife habitat (SWH) for migratory birds may be present in the RSA (OMNR 2000). Although SWH is not a recognized designation on federal lands, it is nevertheless a useful indicator of the value of habitat to species of interest. The lakes and large wetlands in the RSA qualify as candidate waterfowl stopover and staging areas (aquatic). Seven of the waterfowl species identified as indicators for this SWH type have been observed in the RSA to date. Waterfowl surveys during the migration seasons have not been completed and would be required to confirm significance based on the Ontario Ministry of Natural Resources (OMNR) guidelines (OMNR 2000). Nevertheless, CNL considers wetlands greater than 25 ha in area to be significant waterfowl stopover and staging areas based on the definition of a “waterfowl gathering area” in the Quebec Regulation Respecting Standards of Forest Management for Forests in the Domain of the State (chapter A-18.1, r. 7), as well as due to the proximity of the wetlands to the Ottawa River, which is a major migration corridor. The shorelines of lakes, rivers and wetlands in the RSA qualify as candidate shorebird migratory stopover areas, but surveys during the migration seasons have not been completed and would be required to confirm significance. None of the shorebird species identified as indicators for this SWH type have been observed in the RSA to date.

Great blue herons (*Ardea herodias*) have been confirmed breeding in the RSA; one nest with three young was observed in a swamp/marsh during surveys in 2012. However, only breeding colonies containing 10 or more active nests qualify as SWH in the form of colonially-nesting bird breeding habitat (tree/shrub). Although suitable habitat is available in the LSA, no great blue heron colonies representing SWH have been observed during searches to date.

5.6.4.2.2 Habitat Distribution

Most of the RSA is under natural vegetative cover consisting primarily of mixed forest communities (Figure 5.6.4-3). Lakes and wetlands naturally fragment the forest cover and are themselves patchily distributed throughout the RSA. The RSA is likely less fragmented than it was in recent history because of fire suppression and cessation of logging and farmsteading, which have resulted in reforestation. Most of the current human disturbance in the RSA is concentrated in the southeastern two-thirds of the RSA. Mattawa Road and a hydroelectric corridor run through the northern portion of the RSA and Plant Road runs from the CRL main campus through the western portion of the RSA to the rural village of Chalk River. The CRL main campus and WMAs are discrete, isolated disturbances that are not believed to represent major barriers to migratory bird movement since birds are highly mobile and can fly around or over these areas. Several local roads and two hydroelectric corridors cross the LSA, and a portion of the Liquid Dispersal Area is contained within the LSA, but the LSA remains mostly forested (Figure 5.6.4-4). Linear disturbances (roads, trails, hydroelectric corridors) in the LSA and RSA are generally less than 30 m wide and at most 45 m wide. Narrow linear disturbances generally do not represent barriers to bird movement (Desrochers and Hannon 1997; St. Clair et al. 1998), although they may influence territory establishment and delineation (Machtans 2006). Therefore, existing disturbances in the LSA and RSA are unlikely to function as dispersal barriers for migratory birds in the Base Case.

This page left intentionally blank



LEGEND

- HIGHWAY
- ROAD
- TRANSMISSION LINE
- NATURAL GAS PIPELINE
- RIVER/STREAM
- WATERBODY
- WETLAND
- CRL MAIN CAMPUS
- WASTE MANAGEMENT AREA (WMA)[1]
- REGIONAL STUDY AREA (CRL PROPERTY)
- LOCAL STUDY AREA
- SITE STUDY AREA (NSDF PROJECT SITE)
- MIGRATORY BIRD HABITAT

1 0 1
1:35,000 KILOMETRES

NOTE(S)
1. LIQUID DISPOSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.

REFERENCE(S)
1. BASEDATA MNRF 2016 AND CANVEC 2016
2. IMAGERY: © 2010 DIGITALGLOBE IMAGE COURTESY OF USGS EARTHSTAR GEOGRAPHICS SIO © 2017 MICROSOFT CORPORATION
3. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE18N

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
MIGRATORY BIRDS HABITAT AVAILABILITY AND DISTRIBUTION IN THE RSA – BASE CASE

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	LH
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.6.4-3

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm

This page left intentionally blank

232 509220 REPT 004
UNRESTRICTED

LEGEND

- HIGHWAY
- ROAD
- TRANSMISSION LINE
- RIVER/STREAM
- WATERBODY
- WETLAND
- CRL MAIN CAMPUS
- WASTE MANAGEMENT AREA (WMA)[1]
- REGIONAL STUDY AREA (CRL PROPERTY)
- LOCAL STUDY AREA
- SITE STUDY AREA (NSDF PROJECT SITE)
- MIGRATORY BIRD HABITAT

250 0 250

1:10,000 METRES

NOTE(S)

1. LIQUID DISPOSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.

REFERENCE(S)

1. BASEDATA MNRF 2016 AND CANVEC 2016
2. IMAGERY: © 2017 DIGITALGLOBE IMAGE COURTESY OF USGS EARTHSTAR GEOGRAPHICS SIO © 2017 MICROSOFT CORPORATION
3. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE18N

CLIENT

CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT

NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE

MIGRATORY BIRDS HABITAT AVAILABILITY AND DISTRIBUTION IN THE LSA AND SSA – BASE CASE

CONSULTANT

Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	LH
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.6.4-4

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:

25mm

This page left intentionally blank

5.6.4.2.3 Survival and Reproduction

Fifty-five migratory bird species have been recorded in the RSA during surveys, with chestnut-sided warbler (*Setophaga pensylvanica*), veery (*Catharus fuscescens*), white-throated sparrow (*Zonotrichia albicollis*) and black-throated blue warbler (*Setophaga caerulescens*) being the most commonly observed species. An additional 62 species are known to occur in the RSA or potentially occur in the RSA based on habitat availability. Based on the Ontario Breeding Bird Atlas (OBBA) and field observations (where available), 75 species are confirmed breeders, 17 are probable breeders and 24 are possible breeders in or within the vicinity of the RSA, which overlaps primarily with OBBA survey square 18US10, and slightly with OBBA survey squares 18US00 and 18UR19 (Cadman et al. 2007; Appendix 5.6-3). The breeding status of the remaining seven species is unknown in the vicinity of the RSA.

The *State of Canada's Birds 2012* report concluded that bird populations in the Southern Shield and Maritimes region, which includes the RSA, had declined by 13% on average across species groups, and forest birds specifically by 10% since 1970 (North American Bird Conservation Initiative [NABCI] 2012). More broadly, the *State of North America's Birds 2016* report concluded that one-third of all North American bird species, many of which are migratory birds, are in urgent need of conservation action due to declining populations and/or severe threats to their sustainability (NABCI 2016). Although the results from these reports cover broad geographic areas and include species that would not occur in the RSA, they nevertheless demonstrate that migratory birds are of conservation concern and many species are in decline. The largely contiguous forested habitats in the RSA and LSA may be of local and regional benefit to forest-dwelling migratory birds in an increasingly fragmented landscape.

Anthropogenic threats to migratory bird survival and reproduction vary among species because of their diverse ecologies. However, some universal threats that may apply in the RSA are collisions with human infrastructure and collisions with vehicles. Buildings in the CRL main campus and WMAs may pose a collision risk to migratory birds that reside in or migrate through the RSA. Vehicular traffic volume and speed limits in the RSA are low and. therefore, risk of collision with vehicles is expected to be negligible at Base Case.

5.6.4.3 Canada Warbler

5.6.4.3.1 Habitat Availability

The NSDF Project is located in breeding habitat for Canada warblers. Throughout their breeding range, Canada warblers nest in a range of forest types, especially wet forests with a well-developed, dense shrub layer (COSEWIC 2008; Government of Ontario 2015a). This species is commonly found in shrub marshes, red maple stands, cedar (*Thuja* spp.) stands, swamps dominated by black spruce and tamarack (*Larix laricina*), and riparian woodlands (COSEWIC 2008). In the eastern portion of their range, Canada warblers are associated with wet mixed forests and early successional forests (6 to 30 years) created by forest harvesting or natural disturbance (Ball and Bayne 2014; Environment Canada 2016b). Critical habitat has not yet been defined for this species (Environment Canada 2016b). The vegetation community data were used to map suitable habitat for Canada warbler in the LSA and RSA as follows:

- all forest stands in the pre-sapling, sapling and mature age class; and
- wetlands in all age classes.

A total of 119 ha (58.5%) and 1,701 ha (44.1%) of suitable habitat for Canada warbler is estimated to be present in the LSA and RSA, respectively, in the Base Case (Table 5.6.4-4).

Table 5.6.4-4: Breeding Habitat Availability for Canada Warbler in the Base Case

Habitat Suitability	Regional Study Area		Local Study Area	
	Area [ha]	Percent [%]	Area [ha]	Percent [%]
Suitable	1,701	44.1	119	58.5
Unsuitable	2,152	55.9	84	41.5
Total	3,853	100.0	203	100.0

ha = hectare; % = percent.

Disturbances can have both positive and negative effects on Canada warbler habitat availability. Disturbances result in the initial removal of habitat, and Canada warblers are generally absent from recently disturbed areas (0 to 5 years post-disturbance; Norton et al. 2000; Schieck and Song 2006). However, vegetation clearing can improve habitat around the disturbance perimeter by creating shrubby edge habitats that are positively associated with Canada warbler abundance (Ball and Bayne 2014; Collins et al. 1982; Environment Canada 2016b). Firebreaks, utility corridors, and road corridors may have created some suitable habitat for Canada warbler in the Base Case because forest edges generally have denser shrub layers than interior forests.

Fire suppression activities have likely had negative effects on Canada warbler habitat availability relative to what was historically available for this species in the RSA. Shrub density is highest in young regenerating (0 to 24 years) and mature forests because light levels are limited in closed-canopy stands characteristic of mid-seral stages (Alaback 1982; McKenzie et al. 2000). Most forested areas in the RSA are 60 to 80 years old and may not provide preferred habitat for Canada warbler; however, there is some uncertainty associated with the age of forests in the RSA (Section 5.6.8.1.2). Forest stands in the LSA are mostly mature (>80 years old) and structurally complex (Section 5.6.4.1.1), and likely provide highly suitable habitat for Canada warbler in the Base Case.

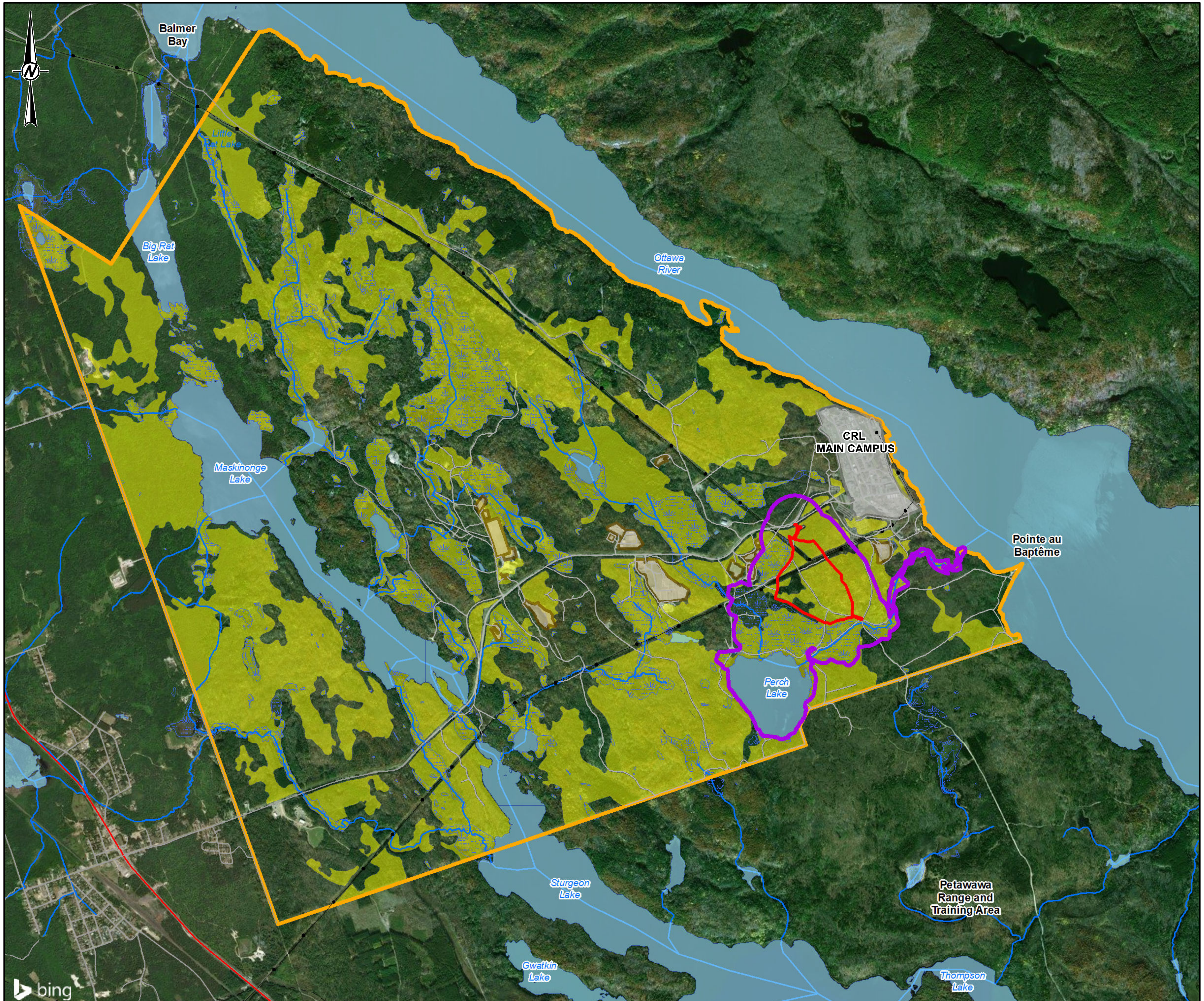
5.6.4.3.2 Habitat Distribution

At Base Case, suitable Canada warbler habitat is well distributed throughout the RSA (Figure 5.6.4-5) and LSA (Figure 5.6.4-6). Habitat does not appear to be a limiting factor for Canada warbler in the Base Case, and this species is highly mobile and can establish territories in new areas. Canada warblers are considered to have widespread, but clumped distribution in the Ottawa Valley Forest Management Unit (Van Dyke 2011).

Effects from habitat fragmentation on Canada warblers are unclear. Some studies suggest that fragmentation has negative effects on Canada warblers because they are an interior-forest nesting species that avoids edge habitat (Askins and Philbrick 1987; Hobson and Bayne 2000). Other studies suggest Canada warblers are resilient to habitat fragmentation because the species uses early successional and dense shrubby habitat that is often associated with habitat disturbance (Schmiegelow et al. 1997; Schmiegelow and Monkkonen 2002). Whether habitat fragmentation from linear disturbances in the LSA and RSA at Base Case has had a positive or negative effect on the distribution of Canada warbler habitat in the RSA remains uncertain.

Habitat does not appear to be a limiting factor for Canada warbler in the Base Case, and this species is highly mobile and can establish territories in new areas. Linear disturbances in the RSA are generally less than 30 m wide and the RSA is composed mostly of forested habitat in patches larger than 10 ha. Similarly, several local roads and two hydroelectric corridors cross the LSA, and a portion of the Liquid Dispersal Area is contained within the LSA, but the LSA remains mostly forested. Narrow linear disturbances generally do not represent barriers to bird movement (Desrochers and Hannon 1997). St. Clair et al. (1998) found that some forest birds were reluctant to cross gaps greater than 50 m, but would cross gaps of 200 m when no other choice existed. Existing disturbances in the RSA do not likely function as dispersal barriers for this species in the Base Case.

This page left intentionally blank



LEGEND

- HIGHWAY
- ROAD
- TRANSMISSION LINE
- NATURAL GAS PIPELINE
- RIVER/STREAM
- WATERBODY
- WETLAND
- CRL MAIN CAMPUS
- WASTE MANAGEMENT AREA (WMA)[1]
- REGIONAL STUDY AREA (CRL PROPERTY)
- LOCAL STUDY AREA
- SITE STUDY AREA (NSDF PROJECT SITE)
- CANADA WARBLER HABITAT

1 0 1
1:35,000 KILOMETRES

NOTE(S)
1. LIQUID DISPOSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.

REFERENCE(S)
1. BASEDATA MNRF 2016 AND CANVEC 2016
2. IMAGERY: © 2017 DIGITALGLOBE IMAGE COURTESY OF USGS EARTHSTAR GEOGRAPHICS SIO © 2017 MICROSOFT CORPORATION
3. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE18N

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
CANADA WARBLER HABITAT AVAILABILITY AND DISTRIBUTION IN THE RSA – BASE CASE

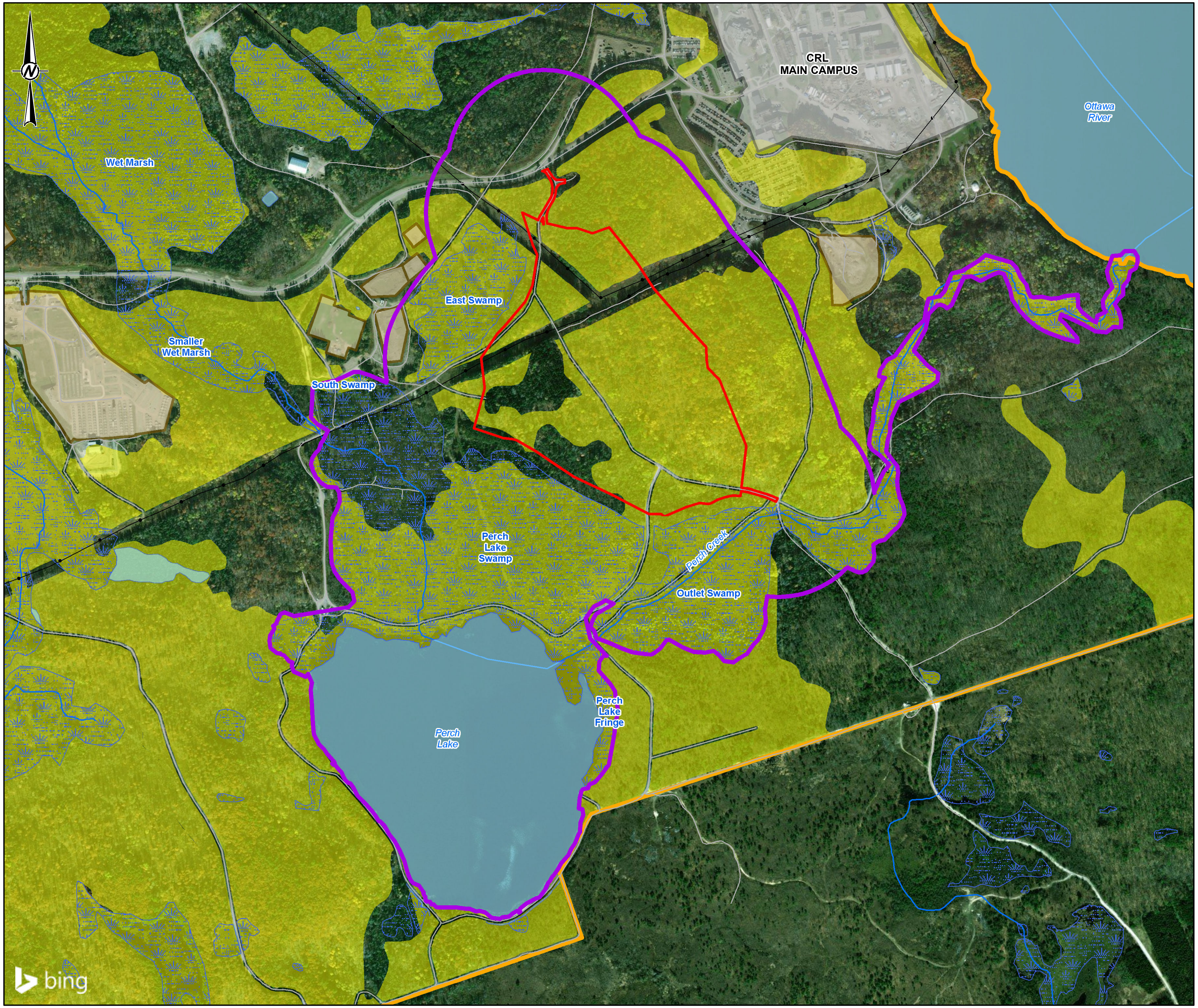
CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	KS
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.6.4-5

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:
25mm

This page left intentionally blank



LEGEND

- HIGHWAY
- ROAD
- TRANSMISSION LINE
- RIVER/STREAM
- WATERBODY
- WETLAND
- CRL MAIN CAMPUS
- WASTE MANAGEMENT AREA (WMA)[1]
- REGIONAL STUDY AREA (CRL PROPERTY)
- LOCAL STUDY AREA
- SITE STUDY AREA (NSDF PROJECT SITE)
- CANADA WABLAR HABITAT

250 0 250
1:10,000 METRES

NOTE(S)
1. LIQUID DISPOSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.

REFERENCE(S)
1. BASEDATA MNRF 2016 AND CANVEC 2016
2. IMAGERY: © 2017 DIGITALGLOBE IMAGE COURTESY OF USGS EARTHSTAR GEOGRAPHICS SIO © 2017 MICROSOFT CORPORATION
3. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE18N

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
CANADA WARBLER HABITAT AVAILABILITY AND DISTRIBUTION IN THE LSA AND SSA – BASE CASE

CONSULTANT

Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	KS
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.6.4-6

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm

This page left intentionally blank

5.6.4.3.3 Survival and Reproduction

Approximately 82% of the Canada warbler breeding range occurs in Canada (Environment Canada 2016b). The Canadian population of this species is estimated to be 3,000,000 individuals (Environment Canada 2016b). Abundance estimates of Canada warbler in Ontario suggest a population of 900,000 individuals or approximately 33% of the Canadian population (COSEWIC 2008). In Ontario, results from the OBBA indicated an annual population decline of 0.8% between the first (1981 to 1985) and second (2001 to 2005) atlas periods (Cadman et al. 2007). Long-term Breeding Bird Survey (BBS) data show a decline of Canada warbler abundance of 4.5% per year from 1968 to 2007 (overall 83% decline; Environment Canada 2016b). Population trends for eastern Canada (Ontario, Quebec, and the Maritimes) all show long-term (1968 to 2007) and short-term (1997 to 2007) declines (COSEWIC 2008).

Because the Canada warbler population in Canada has declined by 83% from 1968 to 2007, it is considered a priority species under the Bird Conservation Strategy for the region, which has the objective of doubling current abundance (Environment Canada 2014). The Canada warbler was designated as threatened by COSEWIC in 2008 and was given the same status under Schedule 1 of SARA in 2010. Despite concerning population trend data, the federal recovery strategy concluded that “there are currently adequate numbers of individuals to sustain the species in Canada or increase its abundance with the implementation of proper conservation actions” (Environment Canada 2016b). The population objective for Canada warbler, as identified in the final federal recovery strategy, is to halt the national decline by 2025, with no more than a 10% decline during this time, and ensure a 10-year positive population trend thereafter (Environment Canada 2016b).

Site-specific surveys in the RSA recorded six Canada warblers in 2007 and seven Canada warblers in 2013. Canada warbler was identified as a confirmed breeder in the OBBA survey square 18US00 and as a possible breeder in the OBBA survey square 18UR19 (Cadman et al. 2007). Canada warblers have been regularly reported in the areas surrounding the RSA (COSEWIC 2008; eBird 2016). Canada warbler has been confirmed during baseline surveys in the LSA and RSA and is assumed to be breeding in suitably habitat throughout the RSA.

The abundance of Canada warblers is positively related to shrub density (Norton and Hannon 1997; Hallworth et al. 2008). The primary threats to Canada warbler habitat include conversion of land for agriculture, removal of the shrub layer (e.g., from forest harvesting or silviculture), forest harvesting, and accidental mortality from collisions with infrastructure (Environment Canada 2015b). Several theories have been suggested as the cause of Canada warbler population decline, including habitat loss and degradation (Ball and Bayne 2014), predation on breeding grounds (Bohning Gaese et al. 1993), and spruce budworm declines (Sleep et al. 2009). A cause-effect relationship has not been established between loss and degradation of wintering habitat and Canada warbler population decline, but loss of primary forest on the wintering grounds is still considered to be a primary potential cause of this species’ decline (Environment Canada 2016b). It is currently unknown whether breeding habitat is limiting in Canada (Environment Canada 2016b).

The Canada warbler primarily feeds on flying insects and spiders. Although Canada warbler will feed on various species of insects, it has been found to feed heavily on spruce budworms during outbreaks. Insect populations are declining worldwide and spruce budworm outbreaks in eastern forests have decreased since 1970; both factors may be contributing to Canada warbler decline (Environment Canada 2016b). Many aerial-foraging insectivorous birds, such as Canada warbler, have experienced large declines since the 1980s (Blancher et al. 2009; NABCIC 2012). The declines suggest a single cause related to insect abundance as both forest and non-forest aerial-foraging birds are declining (Blancher et al. 2009; Nebel et al. 2010;

Nocera et al. 2012; Paquette et al. 2014). Potential causes of reduced availability of insects include habitat loss, changes to timing of peak food abundance from climate change, and pesticide use (Nebel et al. 2010; Nocera et al. 2012; Paquette et al. 2014). Insect and bird populations in the RSA have likely been affected by all of these factors at Base Case. Canada warblers may be susceptible to these factors because their residency on breeding grounds is brief compared to other warblers. Canada warblers are one of the last species to arrive on breeding grounds and one of the first species to leave in the fall (COSEWIC 2008). This behaviour reduces the possibility for raising more than one clutch per year, as well as limits adaptive capability in regards to climate change (Environment Canada 2016b).

5.6.4.4 Eastern Whip-poor-will

5.6.4.4.1 Habitat Availability

The NSDF Project is located in breeding habitat for this species, which is the focus of this assessment. Whip-poor-wills breed in semi-open or patchy forests; wide-open spaces and dense forests are avoided (COSEWIC 2009). Forest structure seems to be more important that forest composition, but whip-poor-wills are most commonly found in dry deciduous or mixed forests throughout most of the species' range (Cink 2002; Beaudry et al. 2010). Whip-poor-wills are also commonly found in rock or sand barrens with scattered trees, old burns, other disturbed sites with early forest succession, and pine plantations (Cink 2002; COSEWIC 2009). This species prefers even-aged successional habitats and is uncommon in mature forests, although individuals may use openings in mature forest areas (Bushman and Therres 1988; Government of Ontario 2015b). Nests require tree cover, shade, sparse ground cover, and need to be in close proximity to open areas for foraging (OMNR 2012a). Utility and road corridors may provide suitable habitat for this species (COSEWIC 2009). Critical habitat has been identified in the federal recovery strategy for this species to be a combination of habitat suitability and habitat occupancy (Environment Canada 2015a). Suitable habitat is divided into nesting and foraging habitat and these must be adjacent to one another to qualify for critical habitat designation (Environment Canada 2015a), and includes the following:

- Suitable nesting habitat is forest with dense tree cover, sparse to moderate shrub and herbaceous cover and well-drained soils.
- Suitable foraging habitat is forest with sparse tree cover or open habitats, dense shrub cover and poorly-drained soils, or agricultural land with scattered shrubs or trees.
- Suitable nesting and foraging habitat is forest with sparse to moderate tree cover or open habitats, sparse to moderate shrub and herbaceous cover and well-drained soils.

The vegetation community data were used to map suitable habitat for eastern whip-poor-will in the LSA and RSA as follows:

- all forest stands in the pre-sapling and sapling age class;
- all forest stands (any age class) within a 50 m buffer around wetlands and aquatic habitat; and
- all forest stands (any age class) within a 50 m buffer along the Ottawa River.

Suitable breeding habitat for eastern whip-poor-will consists of forests adjacent to open habitats. Availability of breeding habitat for eastern whip-poor-will was predicted at Base Case using the vegetation community data (Section 5.6.4.1.3.3). Suitable habitats were mixed, deciduous, and coniferous forests 0 to 34 years of age (i.e., pre-sapling and sapling stages) and forests of any age within 50 m of wetland and aquatic habitats. A total of 9 ha (4.4%) and 769 ha (20.0%) of suitable habitat for eastern whip-poor-will is estimated to be present in the LSA and RSA, respectively, in the Base Case (Table 5.6.4-5).

The RSA overlaps one 10 km x 10 km standardized Universal Transverse Mercator (UTM) grid square identified to contain critical habitat for this species (grid square 18US00; Environment Canada 2015a); however, the area of overlap is small (28 ha). The exact location of critical habitat in grid squares is not identified in recovery strategies, and therefore, it is unknown if critical habitat in grid square 18US00 overlaps with the RSA. Based on habitat mapping, approximately 3 ha of suitable habitat occur in the grid square where it overlaps the RSA.

Table 5.6.4-5: Breeding Habitat Availability for Eastern Whip-poor-will in the Base Case

Habitat Suitability	Regional Study Area		Local Study Area	
	Area [ha]	Percent [%]	Area [ha]	Percent [%]
Suitable	769	20.0	9	4.4
Unsuitable	3,083	80.0	194	95.6
Total	3,853	100	203	100

ha = hectare; % = percent.

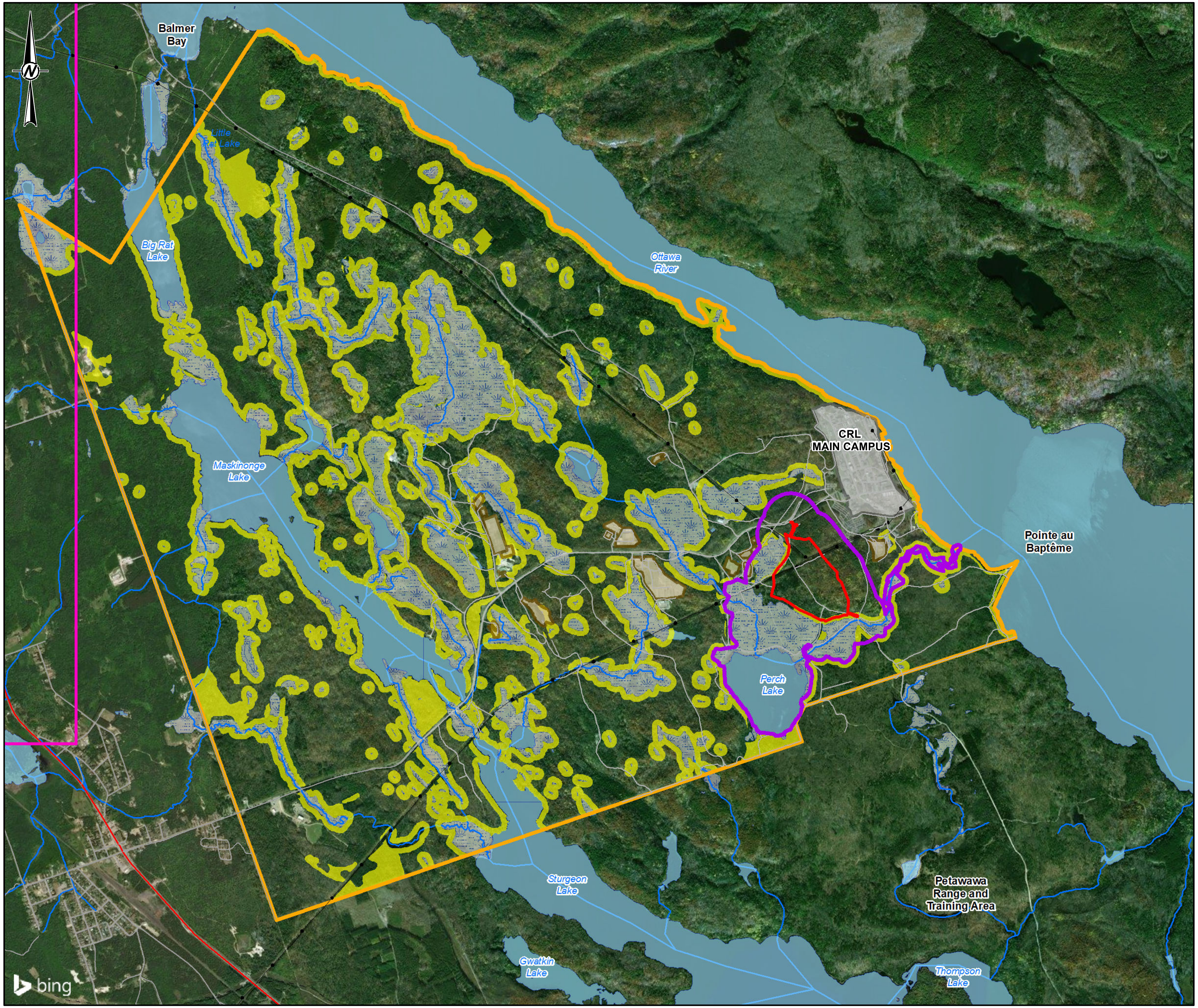
Rock barren habitat is uncommon in the RSA and is predominately found near the Ottawa River shoreline (AECL 2008). Sand barrens have been recorded in the Perch Lake and Maskinonge Lake basins (AECL 2008). Little development has occurred in areas with potential to contain rock and sand barren habitat.

Disturbances can have both positive and negative effects on whip-poor-will habitat availability. Fire suppression activities since the 1940s have likely increased nesting habitat availability relative to what was historically available for this species in the RSA by allowing for natural forest succession. Shrub density is lowest in forests 25 to 100 years old because light levels are limited in these forest stands (Alaback 1982; McKenzie et al. 2000). Most forested areas in the RSA are 60 to 80 years old and may therefore provide suitable nesting habitat for whip-poor-will. On the contrary, fire suppression reduces the availability of open habitat and young forest used as foraging habitat by this species. Firebreaks and road and hydroelectric corridors in the RSA may provide suitable foraging habitat for whip-poor-wills (COSEWIC 2009). Larger disturbance areas, such as the WMAs, may provide suitable foraging habitat, especially areas surrounded by suitable nesting habitat (OMNR 2012a).

5.6.4.4.2 Habitat Distribution

At Base Case, suitable eastern whip-poor-will habitat is well distributed throughout the RSA (Figure 5.6.4-7) and LSA (Figure 5.6.4-8). Habitat does not appear to be a limiting factor for whip-poor-will in the Base Case, and this species is highly mobile and can establish territories in new areas. The 10 km × 10 km standardized UTM grid square identified to contain critical habitat for this species (grid square 18US00; Environment Canada 2015a) overlaps the extreme northwestern tip of the RSA (Figure 5.6.4-7).

Studies suggest that habitat fragmentation may negatively affect this species because whip-poor-wills avoid small, isolated woodlands (Bushman and Therres 1988; COSEWIC 2009). Distance from large forest tract is an important factor influencing the presence of whip-poor-will (COSEWIC 2009). Fragmentation by roads and other linear disturbances is not anticipated to negatively affect whip-poor-will dispersal in the RSA because most linear disturbances are less than 30 m wide and the RSA is composed primarily of forested habitat.



LEGEND

- HIGHWAY
- ROAD
- TRANSMISSION LINE
- NATURAL GAS PIPELINE
- RIVER/STREAM
- WATERBODY
- WETLAND
- CRL MAIN CAMPUS
- WASTE MANAGEMENT AREA (WMA)[1]
- REGIONAL STUDY AREA (CRL PROPERTY)
- LOCAL STUDY AREA
- SITE STUDY AREA (NSDF PROJECT SITE)
- EASTERN WHIP-POOR-WILL HABITAT
- 10 km^2 GRID SQUARE CONTAINING CRITICAL HABITAT

1 0 1

1:35,000 KILOMETRES

NOTE(S)

1. LIQUID DISPOSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.

REFERENCE(S)

1. BASEDATA MNRF 2016 AND CANVEC 2016
2. IMAGERY: © 2017 DIGITALGLOBE IMAGE COURTESY OF USGS EARTHSTAR GEOGRAPHICS SIO © 2017 MICROSOFT CORPORATION
3. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE18N

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
EASTERN WHIP-POOR-WILL HABITAT AVAILABILITY AND DISTRIBUTION IN THE RSA – BASE CASE

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	BB
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.6.4-7

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:

25mm

This page left intentionally blank

LEGEND

- HIGHWAY
- ROAD
- TRANSMISSION LINE
- RIVER/STREAM
- WATERBODY
- WETLAND
- CRL MAIN CAMPUS
- WASTE MANAGEMENT AREA (WMA)[1]
- REGIONAL STUDY AREA (CRL PROPERTY)
- LOCAL STUDY AREA
- SITE STUDY AREA (NSDF PROJECT SITE)
- EASTERN WHIP-POOR-WILL HABITAT

250 0 250

1:10,000 METRES

NOTE(S)

1. LIQUID DISPOSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.

REFERENCE(S)

1. BASEDATA MNRF 2016 AND CANVEC 2016
2. IMAGERY: © 2017 DIGITALGLOBE IMAGE COURTESY OF USGS EARTHSTAR GEOGRAPHICS SIO © 2017 MICROSOFT CORPORATION
3. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE18N

CLIENT

CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT

NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT CHALK RIVER, ONTARIO

TITLE

EASTERN WHIP-POOR-WILL HABITAT AVAILABILITY AND DISTRIBUTION IN THE LSA AND SSA – BASE CASE

CONSULTANT

Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	BB
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.6.4-8

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm

S:\Clients\Canadian_Nuclear_Laboratories\NSDF\99_PROJ\1547525_NSDF_EIS\40_PROD\0009_EIS_Section_5\Section_5_6_Terrestrial\1547525-0009-RT-0009.mxd

This page left intentionally blank

5.6.4.4.3 Survival and Reproduction

Canada probably supports about 6% of the global eastern whip-poor-will population (120,000 individuals; Environment Canada 2015a). Data from the BBS indicate a Canada-wide population decline of 3.19% per year from 2002 to 2012, or 75% loss of the population over this time period (Environment Canada 2015a). Between the first (1981 to 1985) and second (2001 to 2005) OBBA survey periods, whip-poor-wills declined by 37% (Cadman et al. 2007; Environment Canada 2015a).

Because the eastern whip-poor-will population in Canada has declined by 75% from 1968 to 2007, they are considered a priority species under the Bird Conservation Strategy for the region (Environment Canada 2014). The eastern whip-poor-will was designated as threatened by COSEWIC in 2008 and was listed under Schedule 1 of SARA as a threatened species in 2011. Despite concerning population trend data, the federal recovery strategy concluded that individuals that are capable of reproduction are available to sustain the population and improve its abundance (Environment Canada 2015a). The population objective for Canada as identified in the final federal recovery strategy is to halt the national decline by 2025, with no more than a 10% decline during this time, maintain an area of occupancy at 3,000 km^2 or more, and ensure a 10-year positive population trend thereafter, while gradually recolonizing areas in the southern portion of the breeding distribution (Environment Canada 2015a).

Species-specific surveys for whip-poor-will were completed in the RSA in 2013. Four individuals were recorded as using habitats in the RSA. An additional three birds were recorded using habitats outside the RSA. Eastern whip-poor-will was identified as a possible breeder in the OBBA survey square 18US00, but was not recorded in the other OBBA survey squares that overlap the RSA (i.e., 18UR19 and 18US10; Cadman et al. 2007); however, whip-poor-wills have been regularly reported using habitats in areas surrounding the RSA (eBird 2016).

The primary threats to eastern whip-poor-wills are reduced availability of insect prey and habitat conversion for agriculture on wintering grounds (Environment Canada 2015a). Eastern whip-poor-wills feed on many types of flying insects (Cink 2002). Insect populations are declining worldwide and these declines may be contributing to whip-poor-will population decline (COSEWIC 2009; Environment Canada 2015a). Many aerial-foraging insectivorous birds, such as whip-poor-will, have experienced large declines since the 1980s (Blancher et al. 2009; NABCIC 2012). Forest and non-forest aerial-foraging birds have experience drastic population declines, which suggests the major cause of the declines is decreased insect abundance (Blancher et al. 2009; Nebel et al. 2010; Nocera et al. 2012; Paquette et al. 2014). Wagner (2012) noted declines for many nocturnal moth species, which are the preferred prey for eastern whip-poor-will (Cink 2002). Potential causes of reduced availability of insects include habitat loss, climate change resulting in a temporal mismatch between reproduction and peak food abundance, and pesticide use, which can reduce the abundance and diversity of flying insects (Nebel et al. 2010; Nocera et al. 2012; Paquette et al. 2014). Insect and bird populations in the RSA have likely been affected by all of these factors at Base Case. Eastern whip-poor-will may be susceptible to these factors because they are primarily aerial insectivores and they have low annual reproductivity.

5.6.4.5 Golden-winged Warbler

5.6.4.5.1 Habitat Availability

The NSDF Project is located in breeding habitat for this species, which is the focus of this assessment. Golden-winged warbler is a habitat specialist that relies on early successional habitat (10 to 30 years after disturbance) (COSEWIC 2006). Forest type appears to be less important for this species than habitat structure (Confer et al. 2011), but most individuals are found in shrubby, deciduous habitats (Beaudry et al. 2010). Golden-winged warblers prefer habitats with low to moderate canopy cover and moderate shrub and herb cover (Confer et al. 2011). Critical habitat has been identified in the federal recovery strategy for this species to be a combination of habitat suitability and habitat occupancy, where suitable habitat has been identified as the interface (shared edge) between young forest and open habitat in a forest landscape (ECCC 2016c). Nests are often located within 200 m on either side of a forest edge (ECCC 2016c). Where the open habitat contains few shrubs or scattered trees, golden-winged warblers will use the habitat less extensively, outward to about 50 m (ECCC 2016c). Edges can be along roads, trails, cutblocks and other anthropogenic disturbances in addition to natural borders (ECCC 2016c). The vegetation community data were used to map suitable habitat for golden-winged warbler in the LSA and RSA as follows:

- deciduous forest stands (any age class) within 200 m of the forest polygon edge where it abuts open habitat (wetland, aquatic habitat, flooded area, pre-sapling forest of any type, unclassified);
- mixed forest stands (any age class) within 200 m of the forest polygon edge where it abuts open habitat (wetland, aquatic habitat, flooded area, pre-sapling forest of any type, unclassified); and
- 50 m buffer into the following polygon types where they abut deciduous or mixed forest stands (any age class):
  - wetland;
  - flooded area; and
  - pre-sapling forest of any type.

Suitable breeding habitat for golden-winged warbler consists of early successional habitat primarily at the interface of forest and open habitat (i.e., edge habitat). Availability of breeding habitat for golden-winged warbler was predicted at Base Case using the vegetation community data. A total of 94 ha (46.2%) and 2,621 ha (68.0%) of suitable habitat for golden-winged warbler is estimated to be present in the LSA and RSA, respectively, in the Base Case (Table 5.6.4-6). The federal recovery strategy identified focal areas across the species' range that contain core populations that sustain the current breeding distribution and are important for expanding the population into adjacent areas (ECCC 2016c). The RSA falls within focal area GL10, but not in grid squares identified to contain critical habitat within the focal area (ECCC 2016c; Figure 5.6.4-9).

Table 5.6.4-6: Breeding Habitat Availability for Golden-winged Warbler in the Base Case

Habitat Suitability	Regional Study Area		Local Study Area	
	Area [ha]	Percent [%]	Area [ha]	Percent [%]
Suitable	2,621	68.0	94	46.2
Unsuitable	1,232	32.0	109	53.8
Total	3,853	100.0	203	100.0

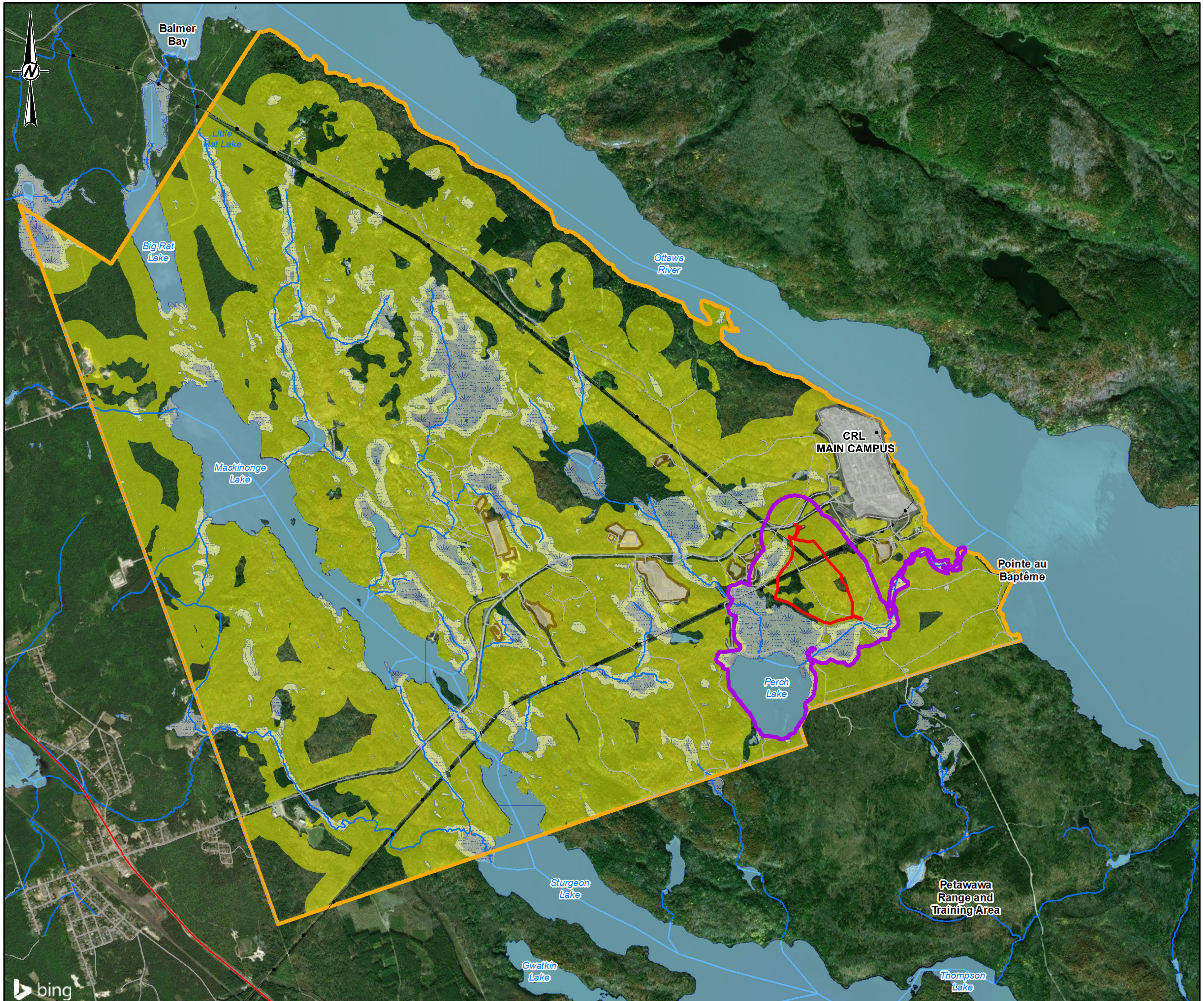
ha = hectare; % = percent.

Disturbances can have both positive and negative effects on golden-winged warbler habitat availability. Fire suppression activities since the 1940s have likely had negative effects on golden-winged warbler habitat relative to what was historically available for this species in the RSA because golden-winged warblers are reliant on early successional habitat. Maturation of young forests is considered a threat to golden-winged warbler populations in Canada (ECCC 2016c). Vegetation clearing can improve habitat around the disturbance perimeter by creating early succession habitats that are positively associated with species abundance (Askins 1994; Beaudry et al. 2010; Confer et al. 2011). However, vegetation clearing can also result in a net loss of habitat. Disturbances with higher edge-to-interior ratios are more likely to have positive effects on golden-winged warbler habitat availability. Edge habitat along firebreaks, utility corridors and roads may provide suitable habitat for golden-winged warbler.

5.6.4.5.2 Habitat Distribution

At Base Case, suitable golden-winged warbler habitat is well distributed throughout the RSA (Figure 5.6.4-9) and LSA (Figure 5.6.4-10). Habitat does not appear to be a limiting factor for golden-winged warbler in the Base Case, and this species is highly mobile and can establish territories in new areas. Habitat fragmentation from linear disturbances present in the LSA and RSA at Base Case has likely had positive effects on golden-winged warbler habitat distribution. Golden-winged warblers are edge habitat specialists, and edge habitat is increased with linear developments. However, extensive habitat fragmentation that results in small forest patches may negatively affect this species; one study found golden-winged warblers did not use forest patches that are smaller than 10 ha (Confer and Knapp 1981). Linear disturbances in the RSA are generally less than 30 m wide and the RSA is composed mostly of forested habitat in patches larger than 10 ha. Similarly, several local roads and two hydroelectric corridors cross the LSA, and a portion of the Liquid Dispersal Area is contained within the LSA, but the LSA remains mostly forested. Narrow linear disturbances generally do not represent barriers to bird movement (Desrochers and Hannon 1997). Further, linear disturbances are less likely to be perceived as movement barriers by edge species such as golden-winged warblers than by interior-forest species. Existing disturbances in the RSA do not likely function as dispersal barriers for this species in the Base Case.

This page left intentionally blank



LEGEND

- HIGHWAY
- ROAD
- TRANSMISSION LINE
- NATURAL GAS PIPELINE
- RIVER/STREAM
- WATERBODY
- WETLAND
- CRL MAIN CAMPUS
- WASTE MANAGEMENT AREA (WMA)[1]
- REGIONAL STUDY AREA (CRL PROPERTY)
- LOCAL STUDY AREA
- SITE STUDY AREA (NSDF PROJECT SITE)
- GOLDEN-WINGED WARBLER HABITAT

1 0 1
1:35,000 KILOMETRES

NOTE(S)
1. LIQUID DISPOSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.

REFERENCE(S)
1. BASEDATA MNRF 2016 AND CANVEC 2016
2. IMAGERY: © 2017 DIGITALGLOBE IMAGE COURTESY OF USGS EARTHSTAR GEOGRAPHICS SIO © 2017 MICROSOFT CORPORATION
3. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE18N

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
GOLDEN-WINGED WARBLER HABITAT AVAILABILITY AND DISTRIBUTION IN THE RSA – BASE CASE

CONSULTANT
Golder Associates

YYYY-MM-DD	2016-12-13
DESIGNED	SO
PREPARED	SO
REVIEWED	KS
APPROVED	

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.6.4-9

This page left intentionally blank

LEGEND

- HIGHWAY
- ROAD
- TRANSMISSION LINE
- RIVER/STREAM
- WATERBODY
- WETLAND
- CRL MAIN CAMPUS
- WASTE MANAGEMENT AREA (WMA)[1]
- REGIONAL STUDY AREA (CRL PROPERTY)
- LOCAL STUDY AREA
- SITE STUDY AREA (NSDF PROJECT SITE)
- GOLDEN-WINGED WARBLER HABITAT

250 0 250

1:10,000 METRES

NOTE(S)

1. LIQUID DISPOSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.

REFERENCE(S)

1. BASEDATA MNRF 2016 AND CANVEC 2016
2. IMAGERY: © 2017 DIGITALGLOBE IMAGE COURTESY OF USGS EARTHSTAR GEOGRAPHICS SIO © 2017 MICROSOFT CORPORATION
3. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE18N

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
GOLDEN-WINGED WARBLER HABITAT AVAILABILITY AND DISTRIBUTION IN THE LSA AND SSA – BASE CASE

CONSULTANT

Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	KS
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.6.4-10

This page left intentionally blank

5.6.4.5.3 Survival and Reproduction

Canada is estimated to support 17% of the global population of golden-winged warblers, with most individuals occurring in Ontario (ECCC 2016c). Historical analysis of golden-winged warblers noted a dramatic population decline of 79% between 1993 and 2002; however, more recent analysis of BBS data suggests that golden-winged warbler populations have been stable between 1970 and 2012 (ECCC 2016c).

Golden-winged warbler is considered a priority species under the Bird Conservation Strategy with the objective of doubling current abundance (Environment Canada 2014). Golden-winged warbler was designated as threatened by COSEWIC in 2006 and was listed under Schedule 1 of SARA as a threatened species in 2007. The population objective for golden-winged warbler, as identified in the federal recovery strategy, is to maintain self-sustaining populations in the focal areas in Manitoba, Ontario, and Quebec, while maintaining, at a minimum, the current abundance of approximately 35,000 pairs in Canada (ECCC 2016c).

Population data are not available for the RSA; however, the RSA falls within one of the focal areas (GL10) identified in the federal recovery strategy to contain core populations that sustain the current breeding distribution and are important for expanding the population into adjacent areas (ECCC 2016c). There are occurrence records for golden-winged warbler throughout the Ottawa Valley Forest Management Unit (Van Dyke 2011). Golden-winged warblers have been recorded in the RSA two times during site-specific surveys, and once during non-site specific surveys (eBird 2016). Golden-winged warbler was identified as a confirmed breeder in the OBBA survey square 18US00, but was not recorded in the other OBBA survey squares that overlap the RSA (i.e., 18UR19 and 18US10; Cadman et al. 2007). Observations of golden-winged warbler were recorded in Chalk River in 1969 and 1970 (eBird 2016). In recent years most observations of golden-winged warbler near the RSA have been reported south of Lac du Bois Dur (eBird 2016).

The primary threat to golden-winged warbler populations is considered to be hybridization with blue-winged warblers (*Vermivora cyanoptera*; ECCC 2016c); however, the current range of blue-winged warbler does not approach the vicinity of the RSA (Gill et al. 2001). Further, a recent study found that only six genomic regions differ between golden-winged and blue-winged warblers (Toews et al. 2016). This suggests golden-winged and blue-winged warblers are the same species, and therefore hybridization may not be a threat to the sustainability of golden-winged warbler populations.

5.6.4.6 Bats

5.6.4.6.1 Habitat Availability

All Canadian bat species have four primary habitat requirements: hibernacula, swarming sites, roosts, and foraging areas. Maternity roost sites and, especially, hibernacula are considered to be the main limiting habitat features for little brown myotis, northern myotis and tri-colored bats within their ranges (COSEWIC 2013). Critical habitat for the three SARA-listed bat species has only been partially identified for hibernacula. Critical habitat for maternity roosts, and summering habitat for roosting and foraging have not yet been formally identified and are the focus of future research effort (Environment Canada 2015b).

Within the RSA, the potential for hibernacula in exposed bedrock that typically forms caves (i.e., karst topography with limestone, dolomite and gypsum-containing minerals) was coarsely assessed at an overview-level. Figure 5.3.1-3, which describes surficial geology in the RSA, indicates the potential for bat hibernacula is low across the RSA, because these mineral types are not present. CNL biologists have not conducted surveys to-date that would confirm the presence or absence of hibernacula or potential hibernacula features within the RSA; however, the potential for hibernacula to be present within the RSA is considered to be low. Foraging habitat requirements are varied between the three species representing this VC and not likely limiting in the environment. As a result, the focus of this assessment is on potential maternity roost habitat.

Based on research conducted to-date on maternity roosting behaviour in natural habitats, older forests are generally preferred by bats, including the three SARA-listed species represented by this VC, likely because of higher snag availability (in the case of little brown myotis and northern myotis; COSEWIC 2013). Snags contain cavities and loose bark required for sheltering roosting females and pups (Environment Canada 2015b). Two of the three species (little brown bat and northern myotis) show a preference for large-diameter (i.e., older) trees and little brown myotis and tri-colored bat females show evidence of philopatry in roost selection (the tendency to return to the same home area following hibernation; COSEWIC 2013; Environment Canada 2015b).

There is considerable variation in preferred roost tree species. Lacki et al. (2007) determined that little brown myotis most often roost in large trembling aspen, but also in white spruce and red spruce. Olson and Barclay (2013) found the majority of roosts located in trembling aspen or balsam poplar. In Alberta's boreal forest, females are known to locate maternity roosts in tall trees of the genus *Populus* (i.e., balsam poplar, trembling aspen, and cottonwood) with early stages of decay, located in old forest stands with moderate canopy cover (Crampton and Barclay 1998). Mature poplar-leading forest stands are common within the RSA. However, preferred roost tree species may vary by region and availability in the forest community.

As a conservative, coarse-scale estimation of potential maternity roost habitat within the RSA that applies to all three bat species, all of the oldest forest stands (i.e., mature age class) of all forest types within the RSA were included. The vegetation community data were used to determine the availability of forests or swamp wetland types with the following characteristics representing recorded maternity roost habitat preferences for little brown myotis and northern myotis:

- mature forest stands (all types; age of trees depending on tree species composition); and
- mature treed swamps (age of trees depending on tree species composition).

Anthropogenic structures such as buildings, bridges and bat boxes are used for maternity roosts by little brown myotis and less commonly by northern myotis (Whitaker et al. 2006). There are no such anthropogenic structures in the SSA.

A total of 1149 ha and 80 ha of suitable maternity roost habitat for bats is estimated to occur in the RSA and LSA, respectively, in the Base Case, comprising 30% of total land cover in the RSA, and 39% of total land cover in the LSA (Table 5.6.4-7). Within the SSA, most of the forested area is suitable, with the exception of the two coniferous forest stands, East Mattawa Road, and two hydroelectric corridors.

Table 5.6.4-7: Maternity Roosting Habitat Availability for Bats in the Base Case

Habitat Suitability	Regional Study Area		Local Study Area	
	Area [ha]	Percent [%]	Area [ha]	Percent [%]
Suitable	1,149	30	80	39
Unsuitable	2,704	70	123	61
Total	3,853	100	203	100

ha = hectare; % = percent.

CNL biologists have conducted acoustic monitoring surveys to determine the composition of the bat community at specific areas within the CNL site since 2014. The 2015 surveys focused on the CRL main campus, and 2016 surveys covered a broader area, including the SSA and LSA. These surveys have determined the presence of all three SARA-listed species, little brown myotis, northern myotis and tri-colored bat, using habitats within the LSA.

Acoustic monitoring is not sufficient to determine the location of roosts or to confirm that habitat within the LSA is used for roosting by bats, because the bats recorded by acoustic monitors could fly several kilometers per night and roost in other areas. However, because of the forest types present in the LSA are consistent with roosting habitat preferences and because SARA-listed bats have been confirmed using this habitat, this assessment applies the precautionary assumption that the habitat is used for maternity roosts.

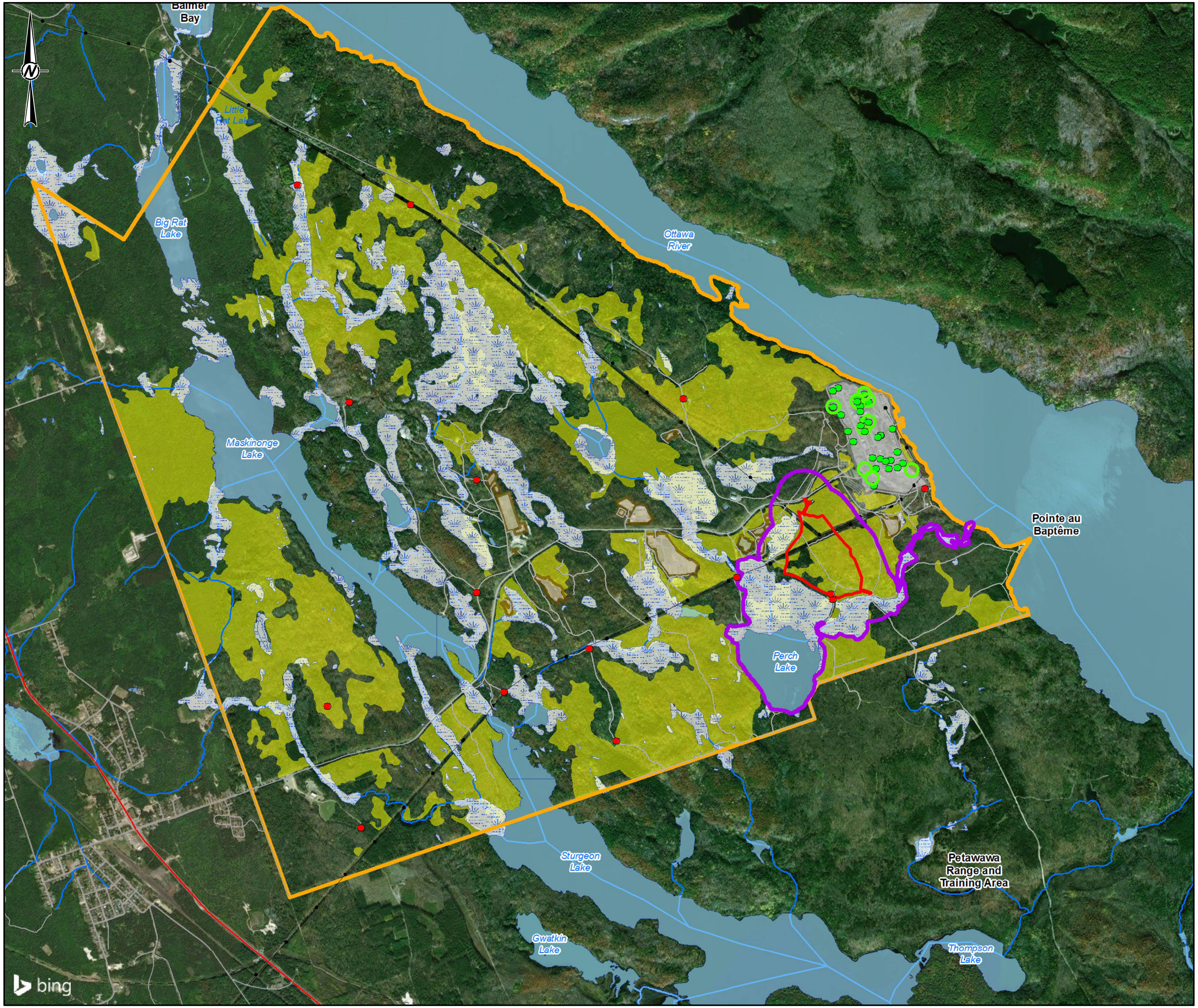
In both the RSA and LSA, stands of high-quality potential maternity roosting habitat for bats are relatively abundant. The majority of the RSA has been undisturbed for the last 75 years as a result of CNL activities. Fire suppression within the RSA has likely had a generally positive effect on the availability of maternity roost tree habitat for little brown myotis and northern myotis, because both of these species are more commonly found roosting in large diameter trees that are present in mature forest stands. Maternity roost characteristics of tri-colored bats are less well known, but are also associated with forested stands (COSEWIC 2013). In addition, suitable foraging habitat in the form of wetlands and riparian areas around the numerous small lakes is also abundant in close proximity to potential roosting habitats.

The CRL main campus, roads and associated infrastructure have likely reduced maternity roosting habitat availability in the RSA in some locations. However, even these changes do not represent a complete loss of potential roosting habitat. Little brown myotis are not considered to be habitat specialists and are well adapted to human disturbance and will use buildings, bat houses and bridges for maternity roosts. Availability of maternity roosting habitat is not likely a limiting factor for bats in the Base Case, within the boundaries of the RSA.

5.6.4.6.2 Habitat Distribution

In the Base Case, potential maternity roost habitat is common, and well-distributed across the RSA (Figure 5.6.4-11) and LSA (Figure 5.6.4-12). Required foraging habitat features (wetlands, open water features such as Perch Lake) are also well distributed and commonly intersperse the potential maternity roosting habitat at both spatial scales. At the regional scale, highest-quality habitat distribution is roughly in a north-south gradient, with the least disturbed areas at the north end of the RSA, and most-disturbed areas in the south end of the RSA, closest to the CRL main campus. Throughout the RSA and LSA, linear features in the form of roads, two hydroelectric corridors, and other gaps in forest cover create gaps and potential commuting corridors, if they are not too wide. All three species generally avoid large clearcuts in forested areas, as well as open areas (COSEWIC 2013; Environment Canada 2015b). Studies in Alberta found the center of clearcuts greater than 30 m from the forest edge were completely avoided by northern myotis and that little brown myotis traveled 2 to 2.5 times less in the center than through the forest edges or along retained stands of trees within the clearcut block (COSEWIC 2013). Tri-colored bats are generally forest-associated and negatively impacted by forest clearing activities (Environment Canada 2015b), but there is less information available about thresholds for maximum gap sizes.

The effects of edges and corridors around mature forest stands on little brown myotis, northern myotis and tri-colored bats are not well known and there are inter-specific differences among them. A number of studies suggest that some degree of forest fragmentation may be beneficial for little brown myotis (Broders and Forbes 2004; Broders et al. 2006; Ethier and Fahrig 2011; Jantzen and Fenton 2013; Segers and Broders 2014). Other studies have found that little brown myotis prefer closed and cluttered canopy areas and avoid edges (Kalcounis and Brigham 1995; Jung et al. 1999; Morris et al. 2010). The forest structure preferred by northern myotis is not well characterized; however, edge habitat around the outer limits of mature forest stands, riparian and cleared corridors (from roads and hydroelectric lines) represent potential foraging and commuting corridors (COSEWIC 2013). Consequently, not only are maternity roost and foraging habitats common in the RSA and LSA in the Base Case, they are also well connected. Within the SSA, high quality potential maternity roosting habitat covers most of the area, with travel corridors in the form of East Mattawa Road and the two hydroelectric corridors interspersed throughout.



LEGEND

- HIGHWAY
- ROAD
- TRANSMISSION LINE
- NATURAL GAS PIPELINE
- RIVER/STREAM
- WATERBODY
- WETLAND
- CRL MAIN CAMPUS
- WASTE MANAGEMENT AREA (WMA)[1]
- REGIONAL STUDY AREA (CRL PROPERTY)
- LOCAL STUDY AREA
- SITE STUDY AREA (NSDF PROJECT SITE)
- POTENTIAL BAT MATERNITY ROOSTING HABITAT [2]

CNL STAFF BAT MONITORING LOCATIONS

- 2016 NO SARA-LISTED SPECIES RECORDED
- 2016 - AT LEAST 1 OF 3 SARA-LISTED SPECIES RECORD
- 2015 NO SARA-LISTED SPECIES RECORDED [2]
- 2015 - AT LEAST 1 OF 3 SARA-LISTED SPECIES RECORD

1 0 1

1:35,000 KILOMETRES

NOTE(S)

1. LIQUID DISPOSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.
2. POTENTIAL BAT MATERNITY ROOSTING HABITAT IS BASED ON HABITAT CONDITIONS, MATERNITY ROOST PRESENCE AND BAT OCCUPANCY HAS NOT YET BEEN VERIFIED.

REFERENCE(S)

1. BASEDATA MNRF 2016 AND CANVEC 2016
2. IMAGERY: © 2017 DIGITALGLOBE IMAGE COURTESY OF USGS EARTHSTAR GEOGRAPHICS SIO © 2017 MICROSOFT CORPORATION
3. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE18N

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
BAT HABITAT AVAILABILITY AND DISTRIBUTION IN THE RSA – BASE CASE

CONSULTANT
Golder Associates

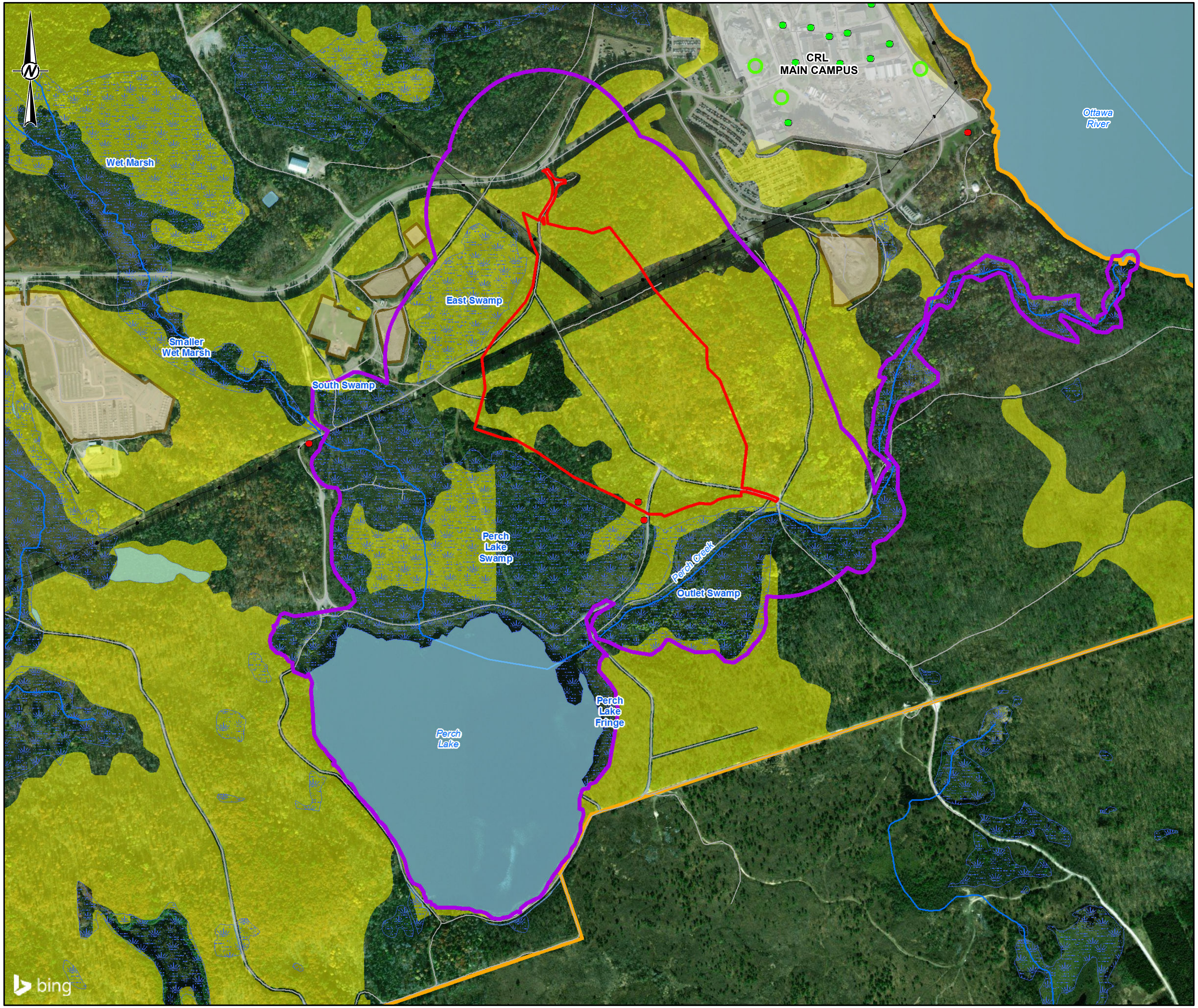
YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	LH
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.6.4-11

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm

S:\Clients\Canadian_Nuclear_Laboratories\NSDF\99_PROJ\1547525_NSDF_EIS\40_PROD\0009_EIS_Section_5\Section_5.6_Terrestrial\1547525-0009-RT-0012.mxd

This page left intentionally blank



LEGEND

- HIGHWAY
- ROAD
- TRANSMISSION LINE
- RIVER/STREAM
- WATERBODY
- WETLAND
- CRL MAIN CAMPUS
- WASTE MANAGEMENT AREA (WMA)[1]
- REGIONAL STUDY AREA (CRL PROPERTY)
- LOCAL STUDY AREA
- SITE STUDY AREA (NSDF PROJECT SITE)
- POTENTIAL BAT MATERNITY ROOSTING HABITAT[2]

CNL STAFF BAT MONITORING LOCATIONS

- 2016 NO SARA-LISTED SPECIES RECORDED
- 2016 - AT LEAST 1 OF 3 SARA-LISTED SPECIES RECORD
- 2015 NO SARA-LISTED SPECIES RECORDED [2]
- 2015 - AT LEAST 1 OF 3 SARA-LISTED SPECIES RECORD

250 0 250

1:10,000 METRES

NOTE(S)

1. LIQUID DISPOSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.
2. POTENTIAL BAT MATERNITY ROOSTING HABITAT IS BASED ON HABITAT CONDITIONS, MATERNITY ROOST PRESENCE AND BAT OCCUPANCY HAS NOT YET BEEN VERIFIED.

REFERENCE(S)

1. BASEDATA MNRF 2016 AND CANVEC 2016
2. IMAGERY: © 2017 DIGITALGLOBE IMAGE COURTESY OF USGS EARTHSTAR GEOGRAPHICS SIO © 2017 MICROSOFT CORPORATION
3. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE18N

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
BAT HABITAT AVAILABILITY AND DISTRIBUTION IN THE LSA AND SSA – BASE CASE

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	LH
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.6.4-12

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm

This page left intentionally blank

5.6.4.6.3 Survival and Reproduction

Little brown myotis and northern myotis occur in every province and territory in Canada (except Nunavut) and approximately 50 and 40%, respectively, of their global range is within Canada. Tri-colored bat occur in Ontario, Quebec, New Brunswick and Nova Scotia, and 10% of their global range is within Canada (Environment Canada 2015b). These three bat species were listed as endangered on Schedule 1 of SARA through an emergency listing order in 2014. The urgency of this listing was due to dramatic population declines caused by white nose syndrome (WNS), which is a fungal disease caused by *Pseudogymnoascus destructans* that affects bats while hibernating.

White-nose syndrome causes physical damage (erosion of the skin, as well as damage to sweat glands, muscles, hair follicles and other tissue), and results in white-grey blotches on the surface of wings and ears, and fuzzy white growth on the muzzle (i.e., the source of the name; Environment Canada 2015b). The physical damage causes bats to arouse from their state of torpor and expend energy that is typically reserved until spring emergence. The change in activity levels and physical damage combined are what eventually causes death (Environment Canada 2015b). Canada is currently divided into WNS-affected and non WNS-affected areas. The province of Ontario, as well as Quebec, New Brunswick, Nova Scotia and PEI are considered WNS-affected and all other provinces and territories are currently non WNS-affected areas.

In general, the total population sizes of bats in Canada are not clearly known based on limitations in survey effort. However, prior to the introduction of WNS, little brown myotis was likely the most common bat species in Canada, with northern myotis also common, and populations of both species might have exceeded one million individuals (COSEWIC 2013). Canadian populations of tri-colored bats were likely less abundant, estimated to be under 20,000 individuals (Environment Canada 2015b). Since detection of WNS in 2010, the recorded population of myotis bats (which includes little brown and northern myotis) has been reduced by 94% in Nova Scotia, New Brunswick, Ontario and Quebec. For tri-colored bat, the estimated reduction in eastern Ontario, Quebec and Nova Scotia populations is also 94% (Environment Canada 2015b).

White-nose syndrome has been estimated to travel at an average rate of 200 to 400 km per year (COSEWIC 2013). It is anticipated that the entire Canadian population of little brown myotis will be impacted by WNS within 11 to 22 years, or possibly sooner based on the recent confirmation of WNS in Washington State (USGS 2016). Based on modelling, little brown myotis is predicted to be functionally extirpated (i.e., less than 1% of existing population) in Canada and the United States by 2026 (COSEWIC 2013); however, this modeling did not consider higher rates of WNS survival in the north portion of the species' range than originally expected. The northern myotis population is expected to have similar declines based on the similarity of their life history characteristics (Environment Canada 2015b). There is less information available about tri-colored bats; however, most of the Canadian range overlaps with the current WNS infection range, and further population declines are anticipated (Environment Canada 2015b).

Little brown myotis, northern myotis and tri-colored bat populations that overlap the RSA are within the WNS-affected area of Canada. Consequently, these populations are particularly susceptible to any additional sources of changes to survival or reproduction because the resilience and adaptability limits of these populations may have been exceeded at Base Case.

Beyond the devastating effects of WNS, other threats to the three species of bat comprising this VC have been recognized as habitat loss and degradation (at hibernacula, maternity roosts and foraging areas), disturbance or harm (through collision with or barotrauma from wind turbines, intentional harm from extermination, or unintentional

harm from creational or scientific disturbances and industrial disturbance), pollution and climate change (Environment Canada 2015b). Little brown myotis in particular are vulnerable to persecution and extermination efforts because of their tendency to roost in anthropogenic structures such as attics (Environment Canada 2015b). Extermination of large colonies can affect local populations, particularly in WNS-affected areas, such as Ontario.

Regarding reproduction and life span, all three bat species are relatively long-lived and have low reproductive rates, making their populations sensitive to increases in adult mortality and slow to recover when the population size is already small. Individuals of little brown myotis have been recorded to live to over 30 years of age (Fenton and Barclay 1980), although the average life span is thought to be shorter (COSEWIC 2013). The life spans of northern myotis and tri-colored bat are at least 15 years (COSEWIC 2013).

Survivorship of all three species is not well understood and there is uncertainty based on deficiencies in study design and analysis used in studies that have reported survival rates. The mean annual survival of little brown myotis in Ontario was 0.82 for males and 0.71 for females. Survival rates are lowest in the first year of age because juveniles often lack sufficient fat reserves needed for hibernation. Females of all three species start breeding after their first year and continue breeding annually. Females give birth to one pup per year (possibly two for tri-colored bat) after 44-60 days of gestation. For little brown myotis, which are more widely studied, reproductive rates seem to decline with increasing latitude; a reproductive rate of greater than 96% was recorded in the eastern United States, with lower rates of 33-74% in the Yukon. In summary, because the RSA is within a WNS-affected area, survival and reproduction of bat populations overlapping the RSA is likely impaired at the Base Case (COSEWIC 2013).

5.6.4.7 Blanding's Turtle

5.6.4.7.1 Habitat Availability

Blanding's turtles are semi-aquatic reptiles that inhabit a variety of aquatic and wetland habitats such as shallow lakes, temporary and permanent ponds, beaver meadows, marshes, swamps, slow-moving rivers and creeks and artificial channels. They prefer aquatic habitats with soft muddy bottoms and abundant aquatic vegetation. They use these habitats for hibernating, mating, foraging, thermoregulation, summer inactivity (i.e., prolonged dormancy during hot or dry periods), and movement (Environment Canada 2016a).

Blanding's turtles hibernate from approximately October to April (ice-off) and partially bury themselves in soft substrates underwater. They emerge from the water to warm themselves or “bask” on available structures close to the water, such as logs, rocks, vegetation hummocks, sedge/grass tussocks, floating mats of aquatic vegetation, muskrat mounds and lodges, or up to 1 m from the water's edge on shorelines and channel banks. Fidelity to overwintering areas has been observed in this species (Environment Canada 2016a).

Although they spend most of their time in aquatic habitats and wetlands, Blanding's turtles also travel seasonally through upland terrestrial habitats to meet important life history requirements, such as nesting (COSEWIC 2005; Lee 1999). In Ontario, Blanding's turtles typically nest from late May through to the first week of July, with a peak of nesting activity in June (Environment Canada 2016a). Nests are typically constructed in open areas such as rock barrens, sand bars, beaches, forest clearings, and meadows. They require loose sandy substrates or organic soils to create nests. Nesting in open areas raises the mean temperature in the nest, resulting in an increased likelihood of nest success (COSEWIC 2005). Females show high nest site fidelity (Environment Canada 2016a).

Blanding's turtles inhabit the RSA and have been the subject of field studies on the CNL site since 2009. Proposed critical habitat for Blanding's turtles has recently been defined in the proposed Recovery Strategy (Environment Canada 2016a) and this definition was applied to the CNL baseline data for this VC. The following steps were undertaken to develop habitat mapping for Blanding's Turtle in the study areas:

1) Map all CNL observation records of Blanding's turtles in the study areas.
2) Within a 2 km radial distance from all observation records identify and include all the permanent and seasonal wetlands and watercourses as proposed critical habitat (based on average home range length observed in Ontario and Quebec; Environment Canada 2016a).
3) Apply a 240 m buffer to all those aquatic and wetland features to incorporate suitable terrestrial habitat into the proposed critical habitat mapping (based on the average distance individuals moved between required resources within the home range; Environment Canada 2016a).
4) All unsuitable habitats that fit the description in the proposed Recovery Strategy (man-made structures, active sand and gravel pits, active agricultural fields and active roadways) were taken out of the proposed critical habitat mapping. Other anthropogenic features, such as powerlines that have low human activity may be used as nesting sites and were considered part of proposed critical habitat. Additionally, large fast flowing rivers act as a barrier to the Blanding's turtle population connectivity and thus proposed critical habitat also is limited by the Ottawa River.

Overall, CNL's 2009-2016 field surveys have been restricted to the southern portion of the RSA. Consequently, only using known observation records to map Blanding's turtle habitat in the RSA would underestimate the extent of proposed critical habitat. Therefore, potential critical habitat was mapped as all remaining permanent and seasonal wetlands and watercourses in the RSA, plus a 240 m buffer around each aquatic or wetland feature.

A total of 168 ha (82.8%) and 2,788 ha (72.4%) of proposed critical habitat for Blanding's turtle is estimated to be present in the LSA and RSA, respectively, in the Base Case (Table 5.6.4-8). An additional 571 ha (14.8%) of potential critical habitat is estimated to be present in the RSA (Table 5.6.4-8).

Table 5.6.4-8: Proposed Critical Habitat and Potential Habitat Availability for Blanding's Turtle in the Base Case

Habitat Suitability	Regional Study Area		Local Study Area	
	Area ha]	Percent [%]	Area [ha]	Percent [%]
Proposed Critical Habitat	2,788	72.4	168	82.8
Potential Critical Habitat	571	14.8	0	0.0
Unsuitable	493	12.8	35	17.2
Total	3,853	100.0	203	100.0

ha = hectare; % = percent.

The RSA contains 521.4 ha and the LSA contains 60.6 ha of wetlands. The SSA is bordered by wetlands to the north, west and south. A large wetland complex consisting of South Swamp and East Swamp abuts the north-west and south-west sides of the NSDF Project site. A riparian wetland associated with Perch Creek is located to the south-east of the NSDF Project site.

There are Blanding's turtle observation records congregated within various waterbodies and wetlands throughout the RSA and LSA. CNL baseline studies indicate that Blanding's turtles use the wetland habitats that surround the NSDF Project site (SSA). The closest observation records for Blanding's turtles are within the riparian corridor of Perch Creek, as well as a roadkill individual on Plant Road at the intersection with East Mattawa Road. CNL confirmed hibernation habitat at various location throughout the RSA including the wetlands approximately 1 km east-southeast of the SSA, and various wetlands northeast of the SSA (north of Plant Road; CNL 2015a).

Perch Lake has the potential to be used as overwintering habitat for Blanding's turtles. This is a eutrophic lake of approximately 45 ha and has a drainage area of 730 ha. The maximum depth of the lake is 3.5 m, and the mean depth is 2 m (Robertson and Barry 1985). The majority of Perch Lake is open water except for the littoral zones, which are shallow wetlands composed of floating, emergent and submerged vegetation that amount to about 30% of the lake's surface (Yankovich et al. 2000). The outer fringe of this zone is known as Perch Lake Marsh. This open marsh may be considered to be part of the lake, within which it is physically continuous. To the north, there are extensive wetlands, notably Perch Lake Swamp, South Swamp, East Swamp and West Swamp. The lake is confined in part by sand outcrops along the northern and southern shores, and by bedrock along the western shores. These sandy areas around Perch Lake have potential as suitable nesting areas for Blanding's turtle; however, CNL's monitoring program did not include nesting surveys and this potential has not been confirmed.

Although the SSA is dominated by forest cover, the roads and hydroelectric corridors provide openings within which suitable turtle nesting habitat may be found. The surficial geology at the SSA consists primarily of sands, underlain by dense sandy silt till containing cobbles and boulders. Consequently, the SSA contains a suitable substrate for nest building. On steep slopes where there is bare ground and sparse vegetation cover, there are patches of exposed sand that have potential for Blanding's turtle nesting habitat. There are sand barrens identified through the SSA and LSA near WMA A (CH2M Gore and Storrie 1998). These sand barrens are in the vicinity of where a Blanding's turtle was found dead on the road in July 2013. These finding suggest that there is the possibility of the sand barrens in this area to be used during nesting (found in nesting period and in suitable habitat); however this is an incidental sighting, and nesting locations for the local populations are undefined. Therefore, there has been no nesting habitat confirmed in the study areas to date.

There are two cleared and maintained hydroelectric corridors for the 115 KV transmission lines through the RSA, one spanning most of the north-south length of the property and the other spanning the southern east-west length of the RSA. These lines intersect in the SSA, and thus, also span the width and length of the LSA. These open areas provide good opportunities for Blanding's turtle nesting because they are areas where eggs would incubate well, increasing the chance of successful hatchling development (COSEWIC 2005). Although these habitats could be suitable for nesting; they also represents ecological traps for the species because they are "active rights-of-way" maintained by Hydro-One and CNL regularly to prevent a loss of Class IV power.

5.6.4.7.2 Habitat Distribution

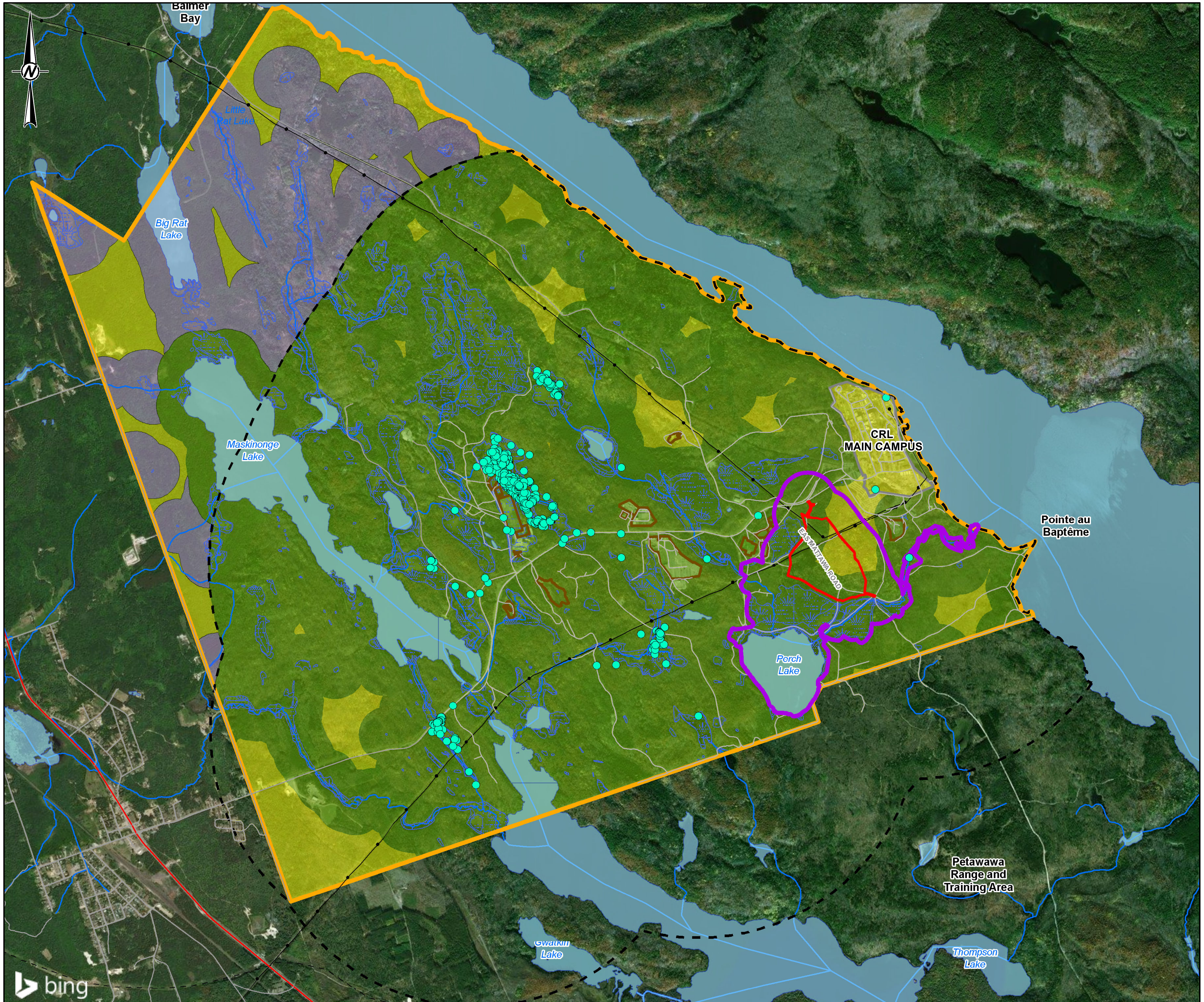
Proposed critical habitat for Blanding's turtles is well distributed throughout the RSA, and where observations of Blanding's turtles have precluded proposed critical habitat mapping, potential critical habitat (wetlands and adjacent 240 m buffer) is well distributed (Figure 5.6.4-13). Shallow wetlands and waterbodies are distributed throughout the LSA and RSA and occupy 101.04 ha of the LSA and 801.94 ha of the RSA. Hydrologically connected wetlands in the RSA either drain to Maskinonge Lake or Perch Lake and eventually to the Ottawa River. The main wetland complex in proximity to the SSA is the Perch Lake Wetland complex. Perch Lake drains to the Ottawa River through Perch Creek, which contains a riparian wetland conducive to Blanding's turtle movement. Little if anything is known about the nesting habitat of Blanding's turtle in the study areas; however, based on the general nesting habitat requirements there are likely nesting areas throughout the SSA, LSA and RSA.

CNL studies have provided some insights into Blanding's turtle movement in the three study areas. Wetlands are natural movement corridors for this species. It is likely that individuals move from the Perch Lake area, north through the wetlands that cross Plant Road, or east through the wetlands that extend along Perch Creek, which flows under Dump Road. CNL has observation records that indicate the use of wetlands throughout the RSA and LSA during the active season. One particular observation of note is within the Perch Creek riparian corridor in the LSA. This riparian corridor connects Perch Lake to the Ottawa River and outlets near a sand covered point of the Ottawa River known a Pointe au Baptême. Pointe au Baptême contains sand dunes and has the potential to be suitable nesting habitat for Blanding's turtles.

There are no Blanding's turtle observation records within the SSA to date; and search efforts by CNL did not confirm any Blanding's turtle nest locations. Based on CNL's extensive knowledge of the site, there are numerous sandy outcrops throughout the LSA and RSA which have the potential to be nesting areas for Blanding's turtle (Figure 5.6.4-14). To highlight a few potential nesting areas within or in proximity to the SSA, the hydroelectric corridors that run through the study areas, particularly within the upland areas containing sandy soils, and the sandy outcrop adjacent to Perch Lake both have the potential to be used as nesting habitat. Hibernation habitat has been confirmed in several wetlands/ waterbodies in the RSA to the north, north-east and east of the SSA. Within the LSA, hibernation habitat for Blanding's turtle is likely in Perch Lake wetland.

During the active season many of CNL's observations of individuals were on roads and trails and along roadside shoulders. This is likely due to the intensive road surveys that CNL undertook; however, this also may indicate that Blanding's turtles are using roads as travel corridors and as potential nesting areas.

This page left intentionally blank



LEGEND

- HIGHWAY
- ROAD
- TRANSMISSION LINE
- NATURAL GAS PIPELINE
- RIVER/STREAM
- WATERBODY
- WETLAND
- CRL MAIN CAMPUS
- WASTE MANAGEMENT SITES (WMA)[1]
- REGIONAL STUDY AREA (CRL PROPERTY)
- LOCAL STUDY AREA
- SITE STUDY AREA (NSDF PROJECT SITE)
- BLANDING'S TURTLE OBSERVATION
- BLANDING'S TURTLE PROPOSED CRITICAL HABITAT
- BLANDING'S TURTLE POTENTIAL HABITAT
- BLANDING'S TURTLE UNSUITABLE HABITAT
- BLANDING'S TURTLE OBSERVATION 2 km RADIUS

1 0 1

1:35,000 KILOMETRES

NOTE(S)

1. LIQUID DISPOSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.

REFERENCE(S)

1. BASEDATA MNRF 2016 AND CANVEC 2016
2. IMAGERY: © 2017 DIGITALGLOBE IMAGE COURTESY OF USGS EARTHSTAR GEOGRAPHICS SIO © 2017 MICROSOFT CORPORATION
3. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE18N

CLIENT

CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT

NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE

BLANDING'S TURTLE HABITAT AVAILABILITY AND DISTRIBUTION IN THE RSA – BASE CASE

CONSULTANT

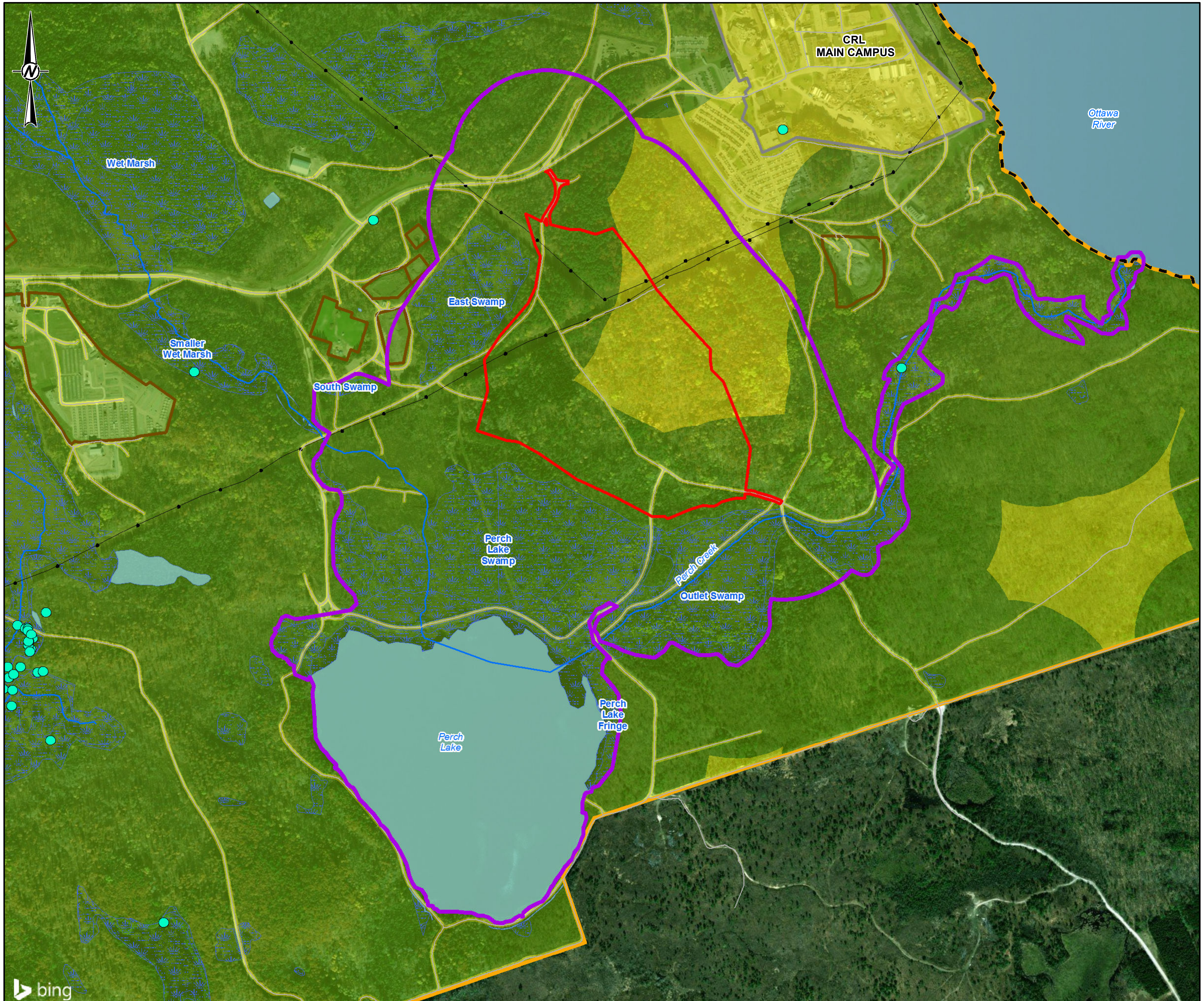
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	EG
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.6.4-13

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm

This page left intentionally blank



LEGEND

- HIGHWAY
- ROAD
- TRANSMISSION LINE
- RIVER/STREAM
- WATERBODY
- WETLAND
- CRL MAIN CAMPUS
- WASTE MANAGEMENT AREA (WMA)[1]
- REGIONAL STUDY AREA (CRL PROPERTY)
- LOCAL STUDY AREA
- SITE STUDY AREA (NSDF PROJECT SITE)
- BLANDING'S TURTLE OBSERVATION
- BLANDING'S TURTLE PROPOSED CRITICAL HABITAT
- BLANDING'S TURTLE UNSUITABLE HABITAT
- BLANDING'S TURTLE OBSERVATION 2 km RADIUS

250 0 250

1:10,000 METRES

NOTE(S)

1. LIQUID DISPOSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.

REFERENCE(S)

1. BASEDATA MNRF 2016 AND CANVEC 2016
2. IMAGERY: © 2010 DIGITALGLOBE IMAGE COURTESY OF USGS EARTHSTAR GEOGRAPHICS SIO © 2017 MICROSOFT CORPORATION
3. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE18N

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
BLANDING'S TURTLE HABITAT AVAILABILITY AND DISTRIBUTION IN THE LSA AND SSA – BASE CASE

CONSULTANT

Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	EG
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.6.4-14

This page left intentionally blank

5.6.4.7.3 Survival and Reproduction

The Blanding's turtles in the RSA belong to the Great Lakes/St. Lawrence population, which is listed as threatened on Schedule 1 of SARA and under the Ontario ESA. The Great Lakes/St. Lawrence population occurs in Ontario and Quebec and its size is estimated at less than 10,000 individuals with fewer than 1,000 reproducing individuals (COSEWIC 2005).

The draft federal recovery strategy states that subpopulations of Blanding's turtles are often isolated from each other and their density is very low, with possibly less than one adult per square kilometre (Environment Canada 2016a). Based on CNL's mark recapture studies in 2014 and 2015, they determined an adult/sub-adult population of 25 ±4 adults within the portion of the RSA that was studied.

As stated, it is not know where female Blanding's turtles of the subpopulation within the RSA are nesting. CNL's mark-recapture study did not include the capture or observation of any hatchlings; however, it should be noted that capture efforts were not expended in the hatchling emergence period (September and October). CNL also noted that there was a relatively low number of juvenile/immature individuals captured during their studies. It is unknown whether this is an indication that juveniles are rare and reflects a low level of recruitment in the population or whether juveniles eluded capture. It has been reported that high annual survivorship of juveniles is required to maintain a stable population of Blanding's turtles on the E. S. George Reserve in Michigan (Congdon et al. 1993).

Roadkill is a particular concern. According to CNL's annual SAR reports, two adult Blanding's turtles have been killed on the roads within the RSA in the last five years. One roadkill occurred on July 7, 2011 on Plant Road and the other occurred on Twin Lakes Road on June 6, 2014. CNL's observation records and road surveys particularly during June and July note a considerable number of turtles travelling on roadways (gravels roads) and near roadsides. This may indicate females in search of nesting sites which makes them susceptible to roadkill. Late maturity, low reproductive output and an extremely long life make this turtle highly vulnerable to adult mortality (Congdon et al. 1993; Environment Canada 2016a). Low reproductive success and low recruitment make this species especially vulnerable to extinction even with a very small increase of the annual mortality rate (<5%) from anthropogenic activities (Gibbs and Shriver 2002).

According to the Ottawa Valley Forest Management Plan, the Ottawa Valley Forest, which encompasses the RSA, is one of the last remaining "strong holds" for Blanding's turtle in Ontario and Canada (Van Dyke 2011). There are occurrence records for this species throughout the Ottawa Valley Forest Management Unit. Available data suggest that Blanding's turtles survive and reproduce successfully in the RSA and that the RSA likely is important for the conservation of this species.

5.6.5 Project Interactions and Mitigation

5.6.5.1 Methods

This section describes the process by which interactions between NSDF Project components and activities and terrestrial biodiversity VCs were identified and evaluated. Potential effect pathways are identified and mitigation developed to eliminate and/or reduce effects is presented. A pathways analysis is then used to focus the assessment on key interactions between the NSDF Project and the environment by evaluating the different effect pathways to determine if, after incorporation of mitigation, there is still potential to cause residual effects. Where effects will be adequately mitigated and are not forwarded for further analysis (i.e., secondary pathways, or where mitigation will remove the pathway altogether), the reasons for concluding the assessment at this stage

are articulated. Primary pathways that may lead to residual effects after incorporation of mitigation are further characterized in subsequent subsections of the assessment (i.e., Section 5.6.1.6). As such the 'Project Interactions and Mitigation' section helps to focus the remainder of the assessment on those interactions (effects pathways) likely to result in residual adverse effects.

The first part of the analysis was to identify the potential effects pathways for all stages of the NSDF Project. The next step in the analysis was the development of environmental design features and mitigation practices that could be incorporated into the NSDF Project to eliminate and/or reduce effects to terrestrial biodiversity VCs. Environmental design features included design elements, environmental best practices, and management policies and procedures. These steps are widely recognized as the most important components of the mitigation hierarchy for biodiversity conservation (BBOP 2015). Environmental design features and mitigation were developed through an iterative process between the engineering and environmental teams, combined with input from project-specific or regional engagement with other interested parties. The design features and/or mitigation were selected considering their effectiveness for implementation and maintenance, and their appropriateness within the context of the identified effect pathways.

Reclamation was not incorporated into the pathway analysis as a means to eliminate interactions between the NSDF Project and the environment because the duration between the impact and reclamation is long and because diverse vegetation communities supporting a range of terrestrial biodiversity features equivalent to that present in the Base Case are not expected on the reclaimed landscape. Upon completion of the installation of the final cover over the ECM, turf-grass will be established. The ECM final cover will be maintained to deter wildlife and avoid the disruption of roots to the cover structure. Consequently, the post-reclamation state of the SSA will be highly modified and unlikely to support terrestrial biodiversity.

After incorporating mitigation, the pathway between each potential interaction of the NSDF Project with terrestrial biodiversity was evaluated and assigned to one of the following categories using scientific knowledge, logic, experience of the professionals conducting the assessment with similar developments, and the demonstrated or expected effectiveness of mitigation:

- **No pathway** – pathway is removed by environmental design features or mitigation so that the NSDF Project would not be expected to result in a measurable environmental change relative to Base Case values, and therefore would have no residual effect on terrestrial biodiversity VCs.
- **Secondary pathway** – pathway could result in a minor measurable change in the environment relative to the Base Case, but this change would have a negligible residual effect on terrestrial biodiversity VCs and is not expected to contribute cumulatively to other NSDF Project effects or other past, present, and reasonably foreseeable developments to cause a significant effect.
- **Primary pathway** – pathway is likely to result in a measurable environmental change relative to the Base Case that could contribute to residual adverse effects on terrestrial biodiversity VCs.

Environmental design features and mitigation that have been or could be incorporated into the NSDF Project to eliminate and/or reduce adverse effects to terrestrial biodiversity VCs were considered. Potential pathways that were completely removed due to implementation of environmental design or mitigation were not assessed further. Pathways that were assessed to be secondary and demonstrated to have a negligible residual effect to terrestrial biodiversity VCs through simple qualitative or semi-quantitative evaluation of the pathway were also not advanced for further assessment. Primary pathways were carried forward for more detailed quantitative and qualitative effects analysis to characterize the residual effects of the NSDF Project on terrestrial biodiversity VCs (see Section 5.5.1.6). In some cases, there was uncertainty associated with the success of proposed mitigation, which contributes to uncertainty for the pathway analysis process. Where uncertainty about potential effect size after mitigation was high, pathways were considered primary.

5.6.5.2 Results

Potential interactions between the NSDF Project and terrestrial biodiversity VCs are presented in Table 5.6.5-1. Mitigations identified to address and, if possible, remove potential interactions between the NSDF Project and terrestrial biodiversity are also integrated into the pathway analysis presented in Table 5.6.5-1. Following the table, assessments for each pathway considered secondary or having no pathway to terrestrial biodiversity VCs are presented, and primary pathways are summarized.

This page left intentionally blank

Table 5.6.5-1: Pathways Analysis for the Terrestrial Biodiversity Valued Components

<table>
<tr><th>Project Activity</th><th>Effects Pathways</th><th>Management Practices and Mitigation Actions</th><th>Pathway Assessment</th></tr>
<tr><td rowspan="6">■ Project activities during the construction phase:
▪ Site Preparation
▪ Construction of the ECM
▪ Blasting
▪ Development of surface water management structures
▪ Construction of the WWTP and other support facilities
▪ On-site road and access development
▪ Haulage of construction materials
▪ Domestic waste (solid and liquid) management
▪ Installation of security and fencing around perimeter of ECM</td><td>Vegetation clearing and grubbing will result in the loss or alteration of existing vegetation and topographical features. This will cause losses of some vegetation communities, and potentially change wildlife habitat availability, use, and connectivity, and could influence wildlife abundance and distribution.</td><td rowspan="2">■ The NSDF Project footprint has been designed to avoid wetlands and limit disturbance to the natural environment to the extent feasible. For example, as the ECM is developed sequentially, undeveloped cells may be prepared and used as stockpile areas to store overburden soils to be used during construction or for daily/interim cover stockpiles. This approach reduces the required area for the laydown and stockpile of materials.
■ A 30 m buffer is established along all identified wetlands near the NSDF site.
■ A 5 m tree-line buffer is established from all property lines on the NSDF site in order to limit disturbance to vegetation and large tree roots at the tree-line</td><td>Primary</td></tr>
<tr><td>Vegetation clearing and grubbing will result in an increase in edge habitat, which could increase predation risk and nest parasitism risk for bird VCs.</td><td>Secondary</td></tr>
<tr><td>Vegetation clearing and grubbing may remove active migratory bird nests and bat roosts, which may influence reproduction and survival (incidental take).</td><td>■ Vegetation clearing and grubbing in the majority of the SSA and particularly in complex forested habitat, will occur before April 8, or after August 31 to avoid effects on nesting birds and bat maternity roosts.
■ If vegetation clearing in small areas with simple habitat that can be effectively searched for nests cannot be conducted outside the breeding bird nesting period (April 8 to August 28), or bat maternity roosting period (May 1 to August 31), pre-clearing bird and bat surveys will be completed to confirm no active nests / roosts are present in trees to be felled. Pre-clearing bird and bat surveys will be completed by Environmental Protection to confirm no active nests/roosts are present in trees to be felled. This work must be approved by Environmental Protection prior to execution and can be denied if the risk to birds or bats is considered high.
■ Species-specific buffers will be put in place around active nests / roosts to avoid disturbance to wildlife caused by noise and other sensory disturbance caused by site preparation activities.
■ Trees will not be felled until the nest / roosts are confirmed inactive and no longer occupied.
■ A 5 m tree-line buffer is established from all property lines on the NSDF site in order to limit disturbance to vegetation and large tree roots at the tree-line</td><td>No Linkage</td></tr>
<tr><td>Fly rock from blasting may result in injury or mortality to wildlife.</td><td rowspan="2">■ A Blasting Plan will be developed and implemented for the NSDF Project.
■ Blasting activities will follow industry standard Best Management Practices and applicable federal regulations.
■ Additional guidance for the NSDF Project blasting limits will be obtained from the Ontario Provincial Standard Specification (OPSS) in the document OPSS 120 – General Specification for Use of Explosives (OPS 2014).
■ Set-back distances required for blasting will be identified in the Blasting Plan.
■ Blasting activities will be temporarily suspended if wildlife are observed in the blasting area.</td><td>No Linkage</td></tr>
<tr><td>Blasting residuals and metals may be released during construction of the ECM and surface water drainage features through the NSDF Project site may transport them directly into downstream waterbodies or adjacent wetlands, affecting surface water and sediment quality and causing changes to wetlands and riparian vegetation communities, which in turn can affect wildlife habitat availability and distribution.</td><td>No Linkage</td></tr>
<tr><td>The construction of the NSDF Project may change downstream discharge, water levels, and channel/bank stability in streams that can cause changes to soils and vegetation communities (including adjacent wetlands), which in turn can affect wildlife habitat availability and distribution</td><td>■ Erosion and sediment control practices (e.g., silt fences, runoff management) applicable to the region and already in place at the CNL property will be used during construction around disturbed areas, where appropriate
■ Where practical, natural drainage patterns will be used to reduce the use of ditches and diversion berms
■ Culverts will be installed or upgraded along site access roads, as necessary, to maintain drainage; all drainage features will be designed to safely convey the flows associated with the probable maximum precipitation event
■ The surface water pond designs will promote infiltration and suspended particulate settling, and will control discharge to the downstream receiving natural systems</td><td>No Linkage</td></tr>
</table>

Table 5.6.5-1: Pathways Analysis for the Terrestrial Biodiversity Valued Components

<table>
<tr><th>Project Activity</th><th>Effects Pathways</th><th>Management Practices and Mitigation Actions</th><th>Pathway Assessment</th></tr>
<tr><td rowspan="5">■ Project activities during the construction phase:
▪ Site Preparation
▪ Construction of the ECM
▪ Blasting (as required)
▪ Development of surface water management structures
▪ Construction of the WWTP and other support facilities
▪ On-site road and access development
▪ Surface water management
▪ Haulage of construction materials
▪ Domestic waste (solid and liquid) management
▪ Installation of security and fencing around perimeter of ECM
■ Project activities during the operation phase:
▪ Staged development of disposal cells in the ECM
▪ On-site transportation of waste and placement in the ECM
▪ Progressive closure of disposal cells and installation of cover
▪ Operation of the WWTP
▪ Existing presence of fencing around perimeter of ECM
▪ Surface water management
▪ Domestic waste (solid and liquid) management; and,
▪ Routine operational management and monitoring activities.</td><td>Sensory disturbance (i.e., lights, smells, noise, human activity, alteration of viewscape) can change wildlife habitat availability, use and connectivity (movement and behaviour), which can lead to changes in wildlife abundance and distribution.</td><td>■ Avoid conducting the activities with highest levels of noise and habitat disturbance during most sensitive life history phase (i.e., breeding and nesting for birds, maternity roosting for bats) by conducting vegetation clearing and grubbing before April 8, or after August 31 to avoid effects on nesting birds, bat maternity roosts and the active Blanding's turtle season.</td><td>Primary</td></tr>
<tr><td>Potential introduction and spread of noxious weed species from trucks and other equipment can affect vegetation community species composition, which can affect wildlife habitat availability and distribution</td><td>■ Implementation of an Integrated Pest Management Program in keeping with best management practices such as the OMNR Forest Management Guide for Conserving Biodiversity at the Stand and Site Scales (OMNR 2010b) to limit effects of noxious and invasive plants on natural vegetation, which includes:
▪ cleaning and inspection of vehicles and equipment prior to NSDF Project site entry;
▪ re-cleaning vehicles and equipment if an area of weed infestation is encountered, prior to advancing to a weed free area; and
▪ locating and managing cleaning locations on the NSDF Project site.</td><td>Secondary</td></tr>
<tr><td>Attraction of wildlife to the NSDF Project (e.g., food waste, petroleum-based products) may increase human-wildlife interactions and change predator-prey relationships, which can affect wildlife survival and reproduction</td><td>■ All wastes that arise as a result of the construction, operations, and closure phases will be safely managed and in accordance with CNL's Waste Management Program.
■ Manage attractants (e.g., collection and storage in appropriate wildlife-resistant containers) to limit interactions between people and wildlife.
■ As per CNL's Management of Land, Habitat and Wildlife Procedure, feeding of wildlife is prohibited to minimize habituation.
■ Provide training to staff and contractors to reinforce the importance of not feeding wildlife and carrying out proper waste management practices.</td><td>Secondary</td></tr>
<tr><td>Movement of heavy equipment and other vehicles on roads and through previously undeveloped / forested areas may cause injury or mortality to Blanding's turtle</td><td rowspan="2">■ Install reptile exclusion fencing around perimeter of the NSDF Project site prior to initiating activities during the construction phase or prior to the active Blanding's turtle season (i.e., prior to April).
■ Repair damaged or ineffective fencing and signage.
■ Develop and implement a road mitigation plan for roads in the LSA (East Mattawa Road, Dump Road, PAB Road and Plant Road) including the location and design of passages for Blanding's turtles under roads and the extent of funnel fencing to direct individuals to the safe crossing structures.
■ Drivers have standard safety training and are provided with environmental awareness training.
■ Enforce existing CNL property speed limits on access roads.
■ Post signs warning drivers of high use wildlife areas and reduce speed limits in these areas.
■ Employees in vehicles encountering wildlife of concern (e.g., Blanding's turtle) on roads are required to communicate the presence of wildlife on the roads to other employees working in the area and to CNL's Environmental Staff.
■ The existing CNL Employee Education Program will be adapted to the NSDF Project prior to construction. All employees and contractors will be trained on the identification and safe handling of Blanding's turtle in order to help the turtle across the road.
■ As per CNL's Management of Land, Habitat, and Wildlife Procedure, dead or wounded animals on roads must be reported to the safety department.
■ Wildlife collisions with vehicles will be monitored, which provides feedback for adaptive management.</td><td>Primary</td></tr>
<tr><td>Installation and maintenance of perimeter fencing will potentially modify movement corridors for Blanding's turtle in the LSA which may increase their travel distances and thus increase the risk of injury/mortality on roads</td><td>Primary</td></tr>
</table>

Table 5.6.5-1: Pathways Analysis for the Terrestrial Biodiversity Valued Components

Project Activity	Effects Pathways	Management Practices and Mitigation Actions	Pathway Assessment
■ Project activities during the construction phase (continued) ■ Project activities during the operation phase (continued):	Movement of heavy equipment and other vehicles on roads and through previously undeveloped / forested areas may cause injury or mortality to bird VCs	■ Reptile exclusion fencing will prevent Blanding's turtles and other reptiles and amphibians from entering the surface water management ponds. ■ Migratory bird exclusion measures will be implemented at the surface water management ponds.	Secondary
	Attraction of wildlife to surface water management ponds may influence wildlife survival and reproduction.		No Linkage
	Vegetation clearing and grubbing activities and hauling activities during operations use vehicles and equipment that combust fuel and emit CACs. These activities involve material handling, vehicles travelling on paved and unpaved roads, and wind erosion of stockpiles that will result in fugitive dust emissions. Air and dust emissions and subsequent deposition may cause a change in soil quality and (directly affecting vegetation communities), which could in turn lead to indirect changes in wildlife habitat availability.	■ Implementation of CNL's Procedure for Management and Monitoring of Emissions, which includes operational control monitoring, verification monitoring and environmental monitoring. ■ The Dust Management Plan for the NSDF Project will be developed and will include: ▪ restricting or suspending activities if unacceptable amounts of dust are generated due to winds or other site conditions; ▪ use of water spraying or misting techniques (e.g., water trucks) as the primary dust control method; ▪ use of fixatives (e.g., chemical suppressant) for dust control during winter season or shutdown periods, and for use as daily/interim cover; ▪ suspension of excavating, loading, hauling, and dumping operations when wind speeds exceed the specified criterion; and ▪ vehicles that have come into contact with contamination will be required to pass through the vehicle decontamination facility. ■ On-site vehicles and equipment engines will meet Tier 2 emission standards and be maintained in good working order. ■ Limit idling of vehicles on-site.	Secondary
	Surface water runoff from the NSDF site can contain contaminants and suspended solids, which can affect soil, water and vegetation quality, ultimately leading to changes to wildlife habitat availability, survival and reproduction.	■ Procedures for surface water management will be developed and implemented for the NSDF Project. ■ The target surface water quality objective is provided by MOECC in Stormwater Management Planning and Design Manual (MOECC 2003). ■ Surface water from all external areas will be conveyed by ditches, swales and culverts to surface water management ponds that will address water quality and water quantity criteria established for the wetland receiving waters and, ultimately, Perch Creek. ■ The surface water management ponds are designed to address erosion and sediment control concerns during construction by providing interim sediment control and by providing water quality/quantity controls during operations, closure, and post-closure. ■ The current surface water management pond footprints reflect the overall storage required to control post-closure flows to predevelopment levels for the 2-year through to 100-year rainfall events at the site. This volume also contains the storage required for sediment control during construction and water quality control during operations. ■ Where drainage crosses roadways, culverts are sized to convey the 25-year design event without road overtopping.	No Linkage
■ Project activities during the operations and closure phases: ▪ Surface water management ▪ Operation of the WWTP ▪ Discharge of treated effluent from the WWTP	Discharge of treated effluent from the WWTP to the East Swamp Wetland can cause changes to groundwater quality in the wetland and downstream surface water quality, which can affect wildlife survival and reproduction.	■ The strategy for wastewater treatment is based on optimizing public and environmental protection by defining an approach to wastewater treatment that uses best demonstrated available technology that is economically achievable (BDATEA), and capable of meeting regulatory requirements. ■ The treatment target for effluent is the CRL Acceptability Criteria for Routine and Non Routine Discharge of Liquids to Stormwaters. ■ Treated effluent will be monitored and confirmed that it meets treatment targets before release to East Swamp Wetland ■ An exfiltration gallery is proposed at the discharge outlet to promote the exfiltration of treated water into the local groundwater regime. ■ Appropriate procedures to identify emergency spill occurrences and response, as well as appropriate response to non-contact surface water or leachate contamination will also be implemented as described in the Operations and Maintenance Plan and Contingency Plan	Secondary

Table 5.6.5-1: Pathways Analysis for the Terrestrial Biodiversity Valued Components

Project Activity	Effects Pathways	Management Practices and Mitigation Actions	Pathway Assessment
	Discharge of treated effluent from the WWTP and outlet from the surface water management ponds can cause changes to hydrology, resulting in scouring of the wetlands, which can affect wildlife habitat availability and distribution.	■ Discharge of treated effluent to the exfiltration gallery area will help to reduce water loss from the hydrogeological system. ■ Outlet flows from all three surface water management ponds will be dispersed by level spreaders that will provide an even flow distribution to the wetland with an appropriately wide dispersal pattern. ■ The WWTP system's outlet utilizes a headwall which discharges to a level spreader for the purposes of preventing erosion and sedimentation at the outlet for the exfiltration gallery. ■ Current surface water management ponds outlet locations are limited by the site boundary (greater than 5 m separation required) so that there is no discharge from the spreader directly to the wetland. ■ Annual maintenance activities will identify any erosion problems. ■ A maintenance review will be completed after major storm events and after the annual spring melt to confirm there are no major erosion issues.	No Linkage
■ Project activities during the operations and closure phases: ▪ Surface water management ▪ Operation of the WWTP ▪ Discharge of treated effluent from the WWTP	Leakage of leachate from the ECM during operations and closure may cause changes to groundwater quality in the wetland and downstream surface water quality, which can affect wildlife survival and reproduction.	■ Design of the ECM includes base contours that have been developed using a herringbone pattern with ridges and valleys to promote leachate transport to the leachate collection system for removal. ■ The base liner design include both primary and secondary liner systems that are designed to have redundancy in case of premature failure and are a combination of natural and synthetic barrier systems. ■ The high-density polyethylene (HDPE) geomembrane for the liner was selected as it is compatible with the leachate generated by the waste and will achieve a long service life. ■ The base liner system will include an underlying compacted clay liner to supplement the primary and secondary liner system. ■ The leachate collection and monitoring system design will provide accessible access points for monitoring, inspections, maintenance, repairs and replacements. ■ Monitoring of the treated effluent discharge will be completed in accordance with CNL's Management and Monitoring of Emissions Procedure.	No Linkage

Table 5.6.5-1: Pathways Analysis for the Terrestrial Biodiversity Valued Components

Project Activity	Effects Pathways	Management Practices and Mitigation Actions	Pathway Assessment
■ Project activities during the closure and post-closure phases: ▪ Maintenance of fencing around perimeter of ECM ▪ Installation of final ECM cover, restoration and grading of SSA ▪ On-going long-term performance monitoring, transfer of NSDF Project into Institutional Control	The installation of the final cover of the ECM and decommissioning of NSDF Project infrastructure may change downstream discharge, water levels, and channel/bank stability in streams that can cause changes to soils and vegetation communities (including adjacent wetlands), which in turn can affect wildlife habitat availability and distribution.	■ The final cover will be designed to promote positive drainage from the NSDF Project site and reduce erosion or abrasion of the cover. ■ Performance monitoring will be completed throughout the post-closure phase for the NSDF Project to confirm that the cover is functioning as intended.	No Linkage
	Leakage of leachate from the ECM during the post-closure phase (i.e., after Year 2400) from liner and cover failure as a result of normal evolution can cause changes to groundwater quality in the wetland and downstream surface water quality, which can affect wildlife survival and reproduction.	■ The final cover is designed to promote positive drainage from the NSDF Project site and reduce erosion or abrasion of the cover. ■ The final cover system will be constructed to promote the shedding of surface water to mitigate infiltration into the mound, and minimize leachate generation. ■ The cover system design incorporates a series of shallow, trapezoidal, riprap-lined drainage channels that are designed to convey water at low velocity. ■ The perimeter road ditch will route the runoff around the ECM perimeter to minimize ponding of water into the closed ECM, erosion of the cover and underlying waste materials, destabilization of the ECM structure, and damage to access roads. ■ The ECM final grading and drainage plan includes collection ditches along the top of the ECM berm road to collect side slope drainage. ■ Performance monitoring will be completed throughout the post-closure phase for the NSDF Project to confirm that the cover is functioning as intended.	Secondary
	Potential introduction and spread of noxious weed species during closure and reclamation can affect vegetation community species composition, which can affect wildlife habitat availability and distribution.	■ Locally-appropriate grass seed mixtures that are certified weed-free will be applied to any cleared and reclaimed areas as soon as practical following construction. ■ Upon completion of the installation of the final cover over the ECM, turf grass will be established and maintained. Maintenance of the final cover includes restricting weed establishment and preventing surface erosion and abrasion.	Secondary

This page left intentionally blank

5.6.5.2.1 No Linkage Pathways

The following pathways were assessed as having no measurable environmental change and hence, no linkage to residual effects on terrestrial biodiversity VCs.

- **Vegetation clearing and grubbing may remove active migratory bird nests and bat maternity roosts, which may influence survival and reproduction.**

The *MBCA* (1994) prohibits the destruction of migratory bird nests during the breeding season. In the RSA, the migratory bird breeding season extends from April 8 to August 28. Little brown myotis, northern myotis and tri-colored bat are listed as endangered on the provincial ESA (2007) and federal SARA (2002). As such, there are prohibitions against killing or harming individuals or destroying a residence, including maternity roosting habitat. Female bats form maternity roost colonies to give birth and raise their young; most young are born in late-June or early-July and are weaned at 26 days of age (COSEWIC 2013). Roosts are also used during the pre-maternity roosting period and swarming period. Therefore, bat roosting period is assumed to be from May 1 to August 31.

Vegetation clearing in the majority of the SSA and particularly in complex forested habitat will be scheduled to occur outside of the migratory bird nesting period (April 8 to August 28) and out of the bat maternity roosting period (May 1 to August 31). Upland areas attractive to migratory birds carry a particularly high risk of disturbing or destroying migratory bird nests or eggs (P. Gregoire, pers. comm. 2013). Because the SSA contains upland areas known to support a diversity of migratory birds, the general use of nest searches as a form of mitigation is not recommended because it is unlikely that all nests would be successfully located. Furthermore, nest sweeps in complex forested habitat in the SSA would likely identify many active nests with overlapping setbacks where clearing could not take place until young have fledged, resulting in schedule delays and additional costs associated with monitoring nest activity. Therefore, every effort will be made to remove vegetation and top soil prior to the nesting and roosting period to minimize nesting attempts and preclude bat roosting.

Pre-clearing bird and bat surveys will be completed by Environmental Protection to confirm no active nests/roosts are present in trees to be felled. This work must be approved by Environmental Protection prior to execution and can be denied if the risk to birds or bats is considered high. If vegetation clearing activities must be completed during the migratory bird nesting period or bat maternity roosting period, they will only occur in small areas and/or areas of simple habitat, where an active search for nests may be carried out successfully if undertaken by experienced observers using widely accepted protocols and including behaviour indicative of nesting (e.g., aggressive, territorial, defensive, distractive behaviour; carrying of faecal sacs, food or nesting material). In addition, a 5 m tree-line buffer is established from all property lines on the NSDF site in order to limit disturbance to vegetation and large tree roots at the tree-line. Nest searches will be completed prior to any clearing or construction activities during the migratory bird nesting period, including in areas that were pre-cleared to account for ground nesting birds.

These mitigation practices are anticipated to avoid any changes to the survival or reproductive success of birds and bats from the NSDF Project relative to baseline conditions. Therefore, this pathway was determined to have no linkage to effects on bird or bat survival and reproduction and is not predicted to affect the maintenance of self-sustaining and ecologically effective bird and bat populations that overlap the RSA.

- **Blasting residuals and metals may be released during construction of the ECM and surface water drainage features through the NSDF Project site may transport them directly into downstream waterbodies adjacent wetlands, affecting surface water and sediment quality and causing changes to wetlands and riparian vegetation communities, which in turn can affect wildlife habitat availability and distribution.**
- **Fly rock from blasting may result in injury or mortality to wildlife.**

Use of explosives during the construction phase of the NSDF Project could cause changes in surface water and soil quality, which has potential to affect wildlife habitat. Explosives have the potential to release nitrogen residual substances (e.g., ammonium nitrate/fuel oil [ANFO]). Blasting activities and the removal of waste rock could increase dust deposition and could increase trace metal (e.g., aluminum, cadmium, chromium, copper, iron, mercury, and silver) concentrations and nitrogen residual substances.

A Blasting Plan will be developed and implemented for the NSDF Project. The Blasting Plan will comply with Fisheries and Oceans Canada (DFO) Guidelines for the Use of Explosives in or Near Canadian Waters (Wright and Hopky 1998) to limit the potential for residual blasting interactions with downstream water quality. The Blasting Plan will also provide mitigation to limit the potential for effects on surface water quality from fugitive dust generation through excavation and material transport. Additional guidance will be obtained from the Ontario Provincial Standard Specification (OPSS) in the document OPSS 120 – General Specification for Use of Explosives (OPS 2014).

Set-back distances required for blasting will be identified in the Blasting Plan. Any runoff in contact with blasting residues at the NSDF Project site will be managed according to the Surface Water Management Plan (e.g., directed to surface water management ponds and associated systems) during the construction phase. In addition, the potential for transporting blasting residuals into downstream waterbodies is minimized as blasting operations are limited to a relatively short period of time during the construction phase. Blasting activities can also cause physical injury or mortality to wildlife. Surface blasting will be temporarily suspended if animals are observed within the danger zone identified by the blast supervisor.

Consequently, the use of explosives for the development of the ECM in the proposed NSDF Project is considered to potentially influence runoff quality with respect to minor increases in nitrate and ammonia concentrations for a short period in the construction phase. As such, blasting activities are not predicted to affect the maintenance of self-sustaining and ecologically effective vegetation communities and wildlife populations that overlap the RSA.

- **The construction of the NSDF Project may change downstream discharge, water levels, and channel/bank stability in streams that can cause changes to soils and vegetation communities, which in turn can affect wildlife habitat availability and distribution.**
- **The installation of the final cover of the ECM and decommissioning of NSDF Project infrastructure may change downstream discharge, water levels, and channel/bank stability in streams that can cause changes to soils and vegetation communities (including adjacent wetlands), which in turn can affect wildlife habitat availability and distribution.**

Changes to surface flows, water levels, and water quality from NSDF Project construction and decommissioning are expected to be limited using environmental design features and mitigation. The NSDF Project footprint was designed to limit disturbance to the natural environment to the extent feasible and will avoid stream and wetland

habitats. For example, as the ECM is developed sequentially, undeveloped cells may be prepared and used as stockpile areas to store overburden soils to be used during construction or for daily/interim cover stockpiles. This approach reduces the required area for the laydown and stockpile of materials. In addition, a 30 m buffer is established along all identified wetlands near the NSDF site. In addition to the wetlands buffer, a 5 m tree-line buffer is established from all property lines on the NSDF site in order to limit disturbance to vegetation and large tree roots at the tree-line. Buildings or structures will not be situated within 5 m of this buffer zone (i.e., 10 m from property line) to provide access for equipment around structures. A buffer zone will also be maintained between the waste and the boundary of the disposal site. This zone provides sufficient area surrounding the facility operations to allow environmental monitoring to be performed, facilitate maintenance, and to allow implementation of contingency measure during an emergency.

All proposed physical works are located within the SSA, affecting a relative small area (4.1%) of the total contributing basin area for Perch Creek (720 ha; Robertson and Barry 1985). Any changes to existing drainage patterns will largely be restricted to this small sub-basin. The total annual volume of contact surface water to be treated is 6,556 m^3. The volume represents approximately 0.38% of the average total outflow from Perch Lake (1,700,000 m^3 per year), or 0.30% of the average total outflow from Perch Creek (2,200,000 m^3 per year). Operational treated effluent discharge is expected to be less than 1 cubic metres per hour (m^3/hr). Flow rates within Perch Creek are approximately 252 m^3/hr; the effluent discharge rate is roughly 0.4% of the average Perch Creek flows and approximately 11.5% of East Swamp Weir flows. Furthermore, the receiving wetlands are expected to buffer the discharge, further reducing flow rates into Perch Creek.

All non-contact and contact surface water will be managed within the NSDF Project site, as per the Surface Water Management Plan that will be developed, reducing the potential for the NSDF Project to affect downstream discharge, water levels, and channel/bank stability. Erosion and sediment control practices (e.g., silt fences, runoff management) applicable to the region and already in place at the CNL property will be used during construction and decommissioning around disturbed areas, where appropriate.

Closure activities include the installation of an engineered cover over the ECM to limit ponding and water infiltration in to the waste. Modification to the drainage ditches and conveyance channels will be made to promote positive drainage from the site and limit erosion or abrasion of the cover. Run-off control for the cover is designed to limit ponding and infiltration of water into the ECM, erosion of the cover and waste material, and destabilization of the structure. The ECM design approach is to control the direction and velocity of the run-off to prevent erosion and abrasion of the cover. Any surface water infiltrating the final cover will be collected by the leachate collection system and sent to the WWTP. The three surface water management ponds will remain to promote infiltration and settlement of suspended solids and restrict discharge rates to the nearby wetland. Decommissioning of the WWTP and all associated surface water management structures will be completed after the leachate quantity and quality no longer requires treatment. In addition, performance monitoring will be completed throughout the post-closure phase for the NSDF Project to confirm that the cover is functioning as intended.

Based on this information, effects to hydrology from changes in the Perch Creek watershed were determined to be negligible (Section 5.4.2.5.2.2). Consequently, these pathways were determined to have a no linkage to effects on vegetation and wildlife habitat availability and distribution. Changes to hydrology are not predicted to affect the maintenance of self-sustaining and ecologically effective vegetation communities and wildlife populations that overlap the RSA.

- **Attraction of wildlife to surface water management ponds may influence wildlife survival and reproduction.**

Surface water is categorized as contact or non-contact run-off. Contact run-off is considered to be contaminated and must be treated by the WWTP. Non-contact (i.e., non-contaminated) run-off is conveyed by ditches and culverts to the three surface water management ponds. All surface water management ponds are designed to address erosion and sediment control during construction (i.e., acting as interim sediment control ponds), and water quality/quantity concerns during operations.

The surface water management ponds will be within the six-foot high, chain link perimeter fence surrounding the NSDF Project, and therefore, not accessible to ground-based wildlife species (e.g., most mammals, herpetofauna). Birds and bats may be attracted to the surface water management ponds, especially during the spring if these ponds are the only open sources of water in the area (i.e., they are ice-free). These open surface water pond features are not predicted to contain any levels of contaminants that would be of concern to wildlife. In addition, the ponds will be small and it is expected that the Ottawa River and other larger natural waterbodies in the RSA and LSA (Perch Lake, specifically) will be more attractive to wildlife than the ponds within the SSA. As such, this pathway was determined to have no linkage to effects on the survival and reproduction of wildlife and is not anticipated to affect the maintenance of self-sustaining and ecologically effective wildlife populations that overlap the RSA.

- **Surface water runoff from the NSDF site can contain contaminants and suspended solids, which can affect soil, water and vegetation quality, ultimately leading to changes to wildlife habitat availability, survival and reproduction.**

The surface water management ponds are designed to address erosion and sediment control concerns during construction by providing interim sediment control and by providing water quality/quantity controls during operations, closure, and post-closure. The current surface water management pond footprints reflect the overall storage required to control post-closure flows to predevelopment levels for the 2-year through to 100-year rainfall events at the site. This volume also contains the storage required for sediment control during construction and water quality control during operations. The target surface water quality objective is provided by MOECC in Stormwater Management Planning and Design Manual (MOECC 2003), which reports a 60% total suspended solids (TSS) removal that provides a basic water quality treatment for discharge to the receiving wetland.

During the construction phase, erosion and sediment control measures will be in place to mitigate the effects of soil erosion and sediment transport. The measures include the use of erosion control blankets, as needed, to control erosion on steep slopes, check dams in ditches and swales, and the three proposed surface water management ponds that will be constructed to serve as interim sediment control facilities during construction, and then as stormwater management facilities during the operations, expansion and post-closure periods. Erosion and sediment control practices (e.g., silt fences, runoff management) applicable to the region and already in place at the CRL property (i.e., CNL's Management of Land and Habitat Procedure) will be used around disturbed areas, where appropriate.

Site operations include surface water management for the ECM and all external areas. Surface water from all external areas will be conveyed by ditches, swales and culverts to surface water management ponds that will address water quality and water quantity criteria established for the wetland receiving waters and, ultimately, Perch Creek. Contact surface water drainage from the active cells of the ECM will be to the WWTP.

Non-contact surface water drainage from completed cells and yet-to-be-activated cells will be directed either by gravity to the external surface water management system or to temporary holding ponds within the ECM, or then pumped to the three surface water management ponds. There will be a need to address pre-treatment of surface water run-off from the active cells prior to conveyance to the WWTP and a need to establish conveyance mechanisms (gravity and pumping) from the interior of the ECM to the surface water management ponds.

Facility inspections will be completed twice annually to confirm that inlets and outlets are clear of debris and to confirm that there are no major erosion issues at the inlet or outlet. As well, the integrity of berms and outlet structures will be confirmed by visual inspections (e.g., to identify any animal burrowing activity or active soil erosion). Inspections will also include an annual sediment level monitoring component within each pond to identify sediment accumulation rates that may require clean-out requirements. If necessary, pond sediment will be extracted by excavation equipment and will be disposed of based on sediment sampling, testing, and classification according to MOECC standards, or stockpiled, de-watered and re-used on-site for ECM cover operations. Sediment removal will follow procedures identified in the Stormwater Management Planning and Design Manual (MOECC 2003).

Roadway, sidewalk, and parking lot winter maintenance activities that may release road salt to the environment, include snow plowing/shoveling and de-icing practices, salt and sand storage and snow stockpiling, removal, and disposal. The current winter maintenance practices outlined in the CRL Salt Management Plan provide for effective management of salt use, and will be applied to the NSDF Project, as necessary. As per the plan, the application of road salt on the NSDF site will be to be limited as salt residual within contact water and/or leachate may compromise the treatment effectiveness of the WWTP systems. Instead, alternative products in winter road management, such as a sand-stone mixtures, are currently being considered.

The implementation of these mitigation measures will reduce the potential for changes to soil, water and vegetation quality from surface water runoff from the NSDF site. As such, this pathway was determined to have no linkage to effects on the abundance of wildlife habitat, and survival and reproduction of wildlife and is not anticipated to affect the maintenance of self-sustaining and ecologically effective wildlife populations that overlap the RSA.

- **Discharge of treated effluent from the WWTP and outlet from the surface water management ponds can cause changed to hydrology, resulting in scouring of the wetlands, which can affect wildlife habitat availability and distribution.**

The major flow system for all three surface water management ponds will discharge to the adjacent wetland and will be dispersed by level spreaders that will provide an even flow distribution to the wetland with an appropriately wide dispersal pattern. The WWTP outlet uses a headwall that discharges to a level spreader for the purposes of preventing erosion and sedimentation at the outlet. An exfiltration gallery is proposed at the discharge outlet to promote the exfiltration of treated water into the local groundwater regime. The proposed surface water management ponds outlet locations are limited by the site boundary (greater than 5 m separation required) so that there will be no discharge from the spreader directly to the wetland. Local topography between the level spreader and the wetland, as well as any setbacks, has influenced the location of the level spreader on site.

Annual maintenance activities will identify erosion issues. Facility inspections will be completed twice annually to confirm that inlets and outlets are clear of debris and to confirm that there are no major erosion issues at the inlet or outlet. In addition, a maintenance review will be completed after major storm events and after the annual spring melt to confirm there are no major erosion issues at the dispersion outlets. As a result of the design of the surface

water management pond outlets, and the proposed low discharge rates (i.e., 1 m^3/hr), the discharge of treated effluent from the WWTP to the East Swamp Wetland is not predicted to result in changes to water levels, flows, and channel/bank stability, that would affect water quality at downstream locations. As a result, this pathway is not predicted to affect the maintenance of self-sustaining and ecologically effective vegetation communities and wildlife populations that overlap the RSA.

- **Leakage of leachate from the ECM during operations and closure may cause changes to groundwater quality in the wetland and downstream surface water quality, which can affect wildlife survival and reproduction.**

Design of the ECM includes base contours that have been developed using a herringbone pattern with ridges and valleys to promote leachate transport to the leachate collection system for removal. The base liner design include both primary and secondary liner systems that are designed to have redundancy in case of premature failure and are a combination of natural and synthetic barrier systems. The primary liner will include a leachate collection system with the secondary liner housing a leak detection system. The composite base liner will contain perforated high-density polyethylene (HDPE) collection and monitoring pipes. The HDPE geomembrane was selected as it is compatible with the leachate generated by the waste and will achieve a long service life. The HDPE geomembrane was selected as it is compatible with the leachate generated by the waste and is expected to perform as an effective hydraulic and diffusion barrier over the 500-year design life (see Section 3.5.2.4). The base liner system will include an underlying compacted clay liner to supplement the primary and secondary liner system. The leachate collection and monitoring system design will provide accessible access points for monitoring, inspections, maintenance, repairs and replacements.

The primary liner system will contain the leachate collection system, and will convey leachate to a single collection point for removal from the mound, and ultimately to the WWTP for treatment. The primary liner system will also protect the natural environment below the mound from leachate migration, and will maintain a maximum depth of leachate on the geomembrane liner of less than or equal to 300 mm. The secondary liner system will contain the leak detection system, which will be used to detect leaks in the unlikely event that the primary liner system fails. The secondary liner will also protect the natural environment from leachate migration if the primary liner system fails. Leachate collected by the leachate collection system will be pumped to the onsite WWTP for treatment.

Designed berms consist of three main geotechnical elements, or layers, each contributing to the soundness and integrity of the berm itself and the whole ECM. A Slope Stability Analysis was completed to provide the information needed to support the design of the base slopes, sidewalls, and side slopes of the ECM. The Slope Stability Analysis addresses the range of anticipated loading conditions, under both short-term and long-term scenarios, to confirm that the slope designs will satisfy minimum factor-of-safety requirements for stability. Size and shape of the berms and each of the elements and layers were determined using a seismic design basis.

The implementation of these mitigation measures will reduce the potential for changes to groundwater and surface water quality from the NSDF site. As such, this pathway was determined to have no linkage to effects on the abundance of wildlife habitat, and survival and reproduction of wildlife and is not anticipated to affect the maintenance of self-sustaining and ecologically effective wildlife populations that overlap the RSA.

5.6.5.2.2 Secondary Pathways

The following pathways were assessed as potentially having a measurable minor environmental change, but negligible residual effect on the terrestrial biodiversity VCs relative to Base Case.

- **Vegetation clearing and grubbing will result in an increase in edge habitat, which could increase predation risk and nest parasitism risk for bird VCs.**

The NSDF Project may increase predation risk by increasing the amount of edge habitat in the LSA. Ground-nesting species are particularly vulnerable to nest predation (Cink 2002) and many predators will use habitat edges as movement corridors (Chalfoun et al. 2002). An increase in edge habitat may also increase the risk of nest parasitism. Fragmentation of forests has increased accessibility for brown-headed cowbirds, which prefer more open habitats (Lowther 1993). However, cowbirds are generally more dispersed and have lower densities in forested areas in the Canadian Shield than south of the Canadian Shield where agricultural land is more common (Lowther 1993). Therefore, nest parasitism risk to bird VCs is not anticipated to increase with construction of the NSDF Project. Increases in edge habitat are not predicted to affect the maintenance of self-sustaining and ecologically effective bird populations that overlap the RSA.

- **Potential introduction and spread of noxious weed species from trucks and other equipment can affect vegetation community species composition, which can affect wildlife habitat availability and distribution.**
- **Potential introduction and spread of noxious weed species during closure and reclamation can affect vegetation community species composition, which can affect wildlife habitat availability and distribution.**

The construction, operation, and closure of the NSDF Project have potential to introduce noxious weed species listed under the provincial *Weed Control Act* (1990). There is also potential to introduce invasive plant species into new areas, which can disrupt plant communities and decrease habitat quality (Mack et al. 2000; Carlson and Shephard 2007; Truscott et al. 2008). Weed species introduced into natural areas have the potential to affect plant community structure and species diversity directly through competition and indirectly through alterations to soil microorganisms, nutrients, and soil moisture (Mack et al. 2000; Truscott et al. 2008).

The majority of weed species introductions arise from human transport (Mack et al. 2000; Reichard and White 2001), and roads also act as dispersal route and habitat for weed establishment (Parendes and Jones 2000). Transportation corridors to and from construction areas provide a means of ingress for noxious weed species through direct dispersion of plant propagules (seeds and/or vegetative parts) from vehicles and machinery, and indirectly through the formation of suitable sites for weeds, in the form of disturbed road edges. Many weed species are able to spread more easily in landscapes that have been fragmented, often become established along edge habitats, such as disturbed road edges associated with transportation corridors (Lafortezza et al. 2010).

Preventing weed species from entering an area is often more efficient and cost effective than dealing with their removal once established (Clark 2003; Polster 2005; Carlson and Shephard 2007). An Integrated Pest Management Program, in keeping with best management practices outlined in the OMNR Forest Management Guide for Conserving Biodiversity at the Stand and Site Scales (OMNR 2010b), will be developed and implemented to limit effects of noxious and invasive plants on natural vegetation. For example, to mitigate the transport and introduction of prohibited, noxious, nuisance, and invasive plant species into new areas, construction equipment will be regularly cleaned on site.

Locally-appropriate grass seed mixtures that are certified weed-free will be applied to any cleared and reclaimed areas as soon as practical following construction. This will reduce the potential for the establishment and spread of invasive plant and weed species. Upon completion of the installation of the final cover over the ECM, turf-grass will be established and maintained. Maintenance of the final cover includes restricting weed establishment and preventing surface erosion and abrasion.

The implementation of these mitigation measures will reduce the potential for introduction of weed species during construction and operation activities. Some localized introduction of weed and invasive species may occur, but mitigation measures to address these identified in Table 5.6.5-1 would result in minor changes to the abundance and distribution of plant populations and communities relative to baseline conditions. Therefore, this interaction was determined to have a negligible residual effect on vegetation and wildlife habitat availability and distribution. Introduction of weed species is not predicted to affect the maintenance of self-sustaining and ecologically effective vegetation communities and wildlife populations in the RSA.

- **Attraction of wildlife to the NSDF Project (e.g., food waste, petroleum based products) may increase human-wildlife interactions and change predator-prey relationships, which can affect wildlife survival and reproduction**

Food smells and other aromatic compounds such as petroleum-based chemicals can attract carnivores to human developments (Benn and Herrero 2002; Peirce and Van Daele 2006; CWS 2007; Beckmann and Lackey 2008). In addition, infrastructure, such as buildings (e.g., the administration office building, which will be installed and used during construction and remain through operations), may also attract carnivores as it can serve as a refuge to escape extreme heat or cold (CWS 2007). Corvids (e.g., crows and ravens) and raptors may also be attracted to infrastructure and anthropogenic food sources (Restani et al. 2001; Marzluff and Neatherlin 2006; CWS 2007; Kristan and Boarman 2007; Baxter and Allan 2008). Attraction of carnivores and predatory birds (e.g., ravens and gulls) to the NSDF Project can increase predation pressure on VC prey species (e.g., passerines and waterfowl), and may cause local declines in abundance in these prey species (Monda et al. 1994; CWS 2007; Liebezeit et al. 2009).

The attraction of wildlife to the NSDF Project also has the potential to increase human-wildlife interactions, which may result in the removal of wildlife by mortality or relocation. The implementation of the mitigation summarized in Table 5.6.5-1 and in the CNL's Waste Management Program and Management of Land, Habitat, and Wildlife Procedure is anticipated to limit the attraction of wildlife to the site and result in minor changes in survival and reproduction from problem wildlife and altered predator-prey relationships relative to Base Case conditions. Subsequently, this pathway is expected to have a negligible net effect on wildlife abundance, and is not predicted to affect the maintenance of self-sustaining and ecologically effective populations that overlap the RSA.

- **Movement of heavy equipment and other vehicles on roads and through previously undeveloped/forested areas may cause injury or mortality to bird VCs.**

The NSDF Project will increase vehicle traffic during construction, which could result in increased injury and mortality to bird VCs. The risk of vehicle-wildlife collisions is not uniform in regards to species, species with small size and slow movement speeds (e.g., amphibians and turtles) have a higher mortality risk from crossing roads than larger and more mobile species (e.g., birds; Hels and Buchwald 2001; Fahrig and Rytwinksi 2009).

Traffic speed and volume are the primary factors that contribute to road-related wildlife mortality. Speed limits will be clearly posted on access roads and enforced to mitigate against potential wildlife mortalities during construction, operation, and decommissioning. In addition, drivers will have standard safety training and are provided with environmental awareness training. Because of the mitigation measures that will be applied, increases in vehicle traffic during NSDF Project construction, operation, and decommissioning are expected to result in minor changes to wildlife populations as compared to baseline conditions. Therefore, collisions with NSDF Project vehicles are expected to have negligible residual effects on wildlife populations and are not predicted to affect the maintenance of self-sustaining and ecologically effective avian populations that overlap the RSA.

- **Vegetation clearing and grubbing activities and hauling activities during operations use vehicles and equipment that combust fuel and emit CACs. These activities involve material handling, vehicles travelling on paved and unpaved roads, and wind erosion of stockpiles that will result in fugitive dust emissions. Air and dust emissions and subsequent deposition may cause a change in soil quality and (directly affecting vegetation communities), which could in turn lead to indirect changes in wildlife habitat availability.**

Construction and operation of the NSDF Project will generate air and dust emissions such as carbon monoxide (CO), oxides of sulphur (SOx includes sulphur dioxide [SO_2]), oxides of nitrogen (NOx includes nitrogen dioxide NO_2), particulate matter ($PM_{2.5}$), and suspended particulate matter (SPM). Air emissions such as SOx and NOx can result from the use of fossil fuels in generators, vehicles and machinery. Vehicle exhaust and fugitive dust from unpaved and paved roads is the largest contributor to particulate matter (SPM, PM_{10}, and $PM_{2.5}$) during both construction and operations (Section 5.2.1.6.2).

Air and dust emissions, and subsequent deposition can change soil quality and alter vegetation and wetlands, which can adversely influence wildlife habitat availability and distribution. Sulphur dioxide and NO_x from combustion of fossil fuels and dust deposition can affect soil pH and nutrient content, and soil fauna composition (Rusek and Marshall 2000). Changes in soil quality (physical, chemical and biological properties) can affect plant community composition, structure and diversity (Grantz et al. 2003; Peachey et al. 2009). Dust that falls directly on plants also can have a physical effect by smothering plant leaves or blocking stomata openings (Farmer 1993; Grantz et al. 2003). Plant species have different levels of tolerance to dust deposition, which can result in changes to above ground biomass and species composition. For example, bryophyte and lichens can be sensitive to the chemical effects of dust because they obtain moisture and nutrients from the atmosphere and immediate surroundings, including substances that are trapped or deposited directly on the surface of the bryophyte leaf or lichen thalli (Farmer 1993). Bryophytes and lichens may experience the largest effects close to roads where the greatest amount of deposition frequently occurs (Auerbach et al. 1997). Rates of dust deposition and accumulation are dependent on the rate of supply from the source, wind speed, precipitation events, topography, and vegetation cover.

Dust control will be conducted to support waste placement operations in accordance with the Dust Management Plan during loading, transportation, placement and compaction operations. Work areas that have the potential for generating dust will require dust suppression techniques and monitoring. The primary dust control method will include water spraying or misting techniques (e.g., water trucks). Water application is controlled to avoid generation of free liquids. Fixatives (e.g., chemical suppressant) may also be used for dust control during winter season or shutdown periods, and for use as daily/interim cover. The use of fixatives is reviewed prior to application for potential effects on leachate and surface water runoff generated by the ECM.

Vehicle exhaust and fugitive dust from unpaved roads is the largest contributor to particulate matter (SPM, PM_{10}, and $PM_{2.5}$) during both the construction and operations phases. Vehicle exhaust during the construction of the ECM is the largest contributor of NO_x/NO_2 and CO. Predicted concentrations for the Application Case during both construction and operations phases are below applicable air quality guidelines and/or standards (Section 5.2.1.6.2, Table 5.2.1-14). The World Health Organization (WHO) has established annual critical levels at which vegetation growth and community composition characteristics may be altered due to SO_2 and NO_x emissions (WHO 2000). The maximum modelled annual SO_2 (1.06 μg/m^3) and NO_2 (19.31 μg/m^3) concentrations at the local study area boundary are also below the WHO critical levels of 20 μg/m^3 and 30 μg/m^3, respectively (WHO 2000).

With the implementation of mitigation summarized in Table 5.6.5-1 and in CNL's Management and Monitoring of Emissions Procedure and through the implementation of the Dust Management Plan for the NSDF Project., air and dust emissions and subsequent deposition are expected to result in minor and local changes to soil quality and vegetation communities relative to Base Case conditions. Therefore, this pathway was determined to have a negligible net effect on wildlife habitat availability and distribution. Air and dust emissions are not predicted to affect the maintenance of self-sustaining and ecologically effective vegetation communities and wildlife populations that overlap the RSA.

- **Discharge of treated effluent from the WWTP to the East Swamp Wetland can cause changes to groundwater quality in the wetland and downstream surface water quality, which can affect wildlife survival and reproduction.**

The WWTP for the NSDF Project will be a new, stand-alone facility with a new discharge point. The WWTP will treat leachate generated in the ECM during operations and the closure periods. The strategy for wastewater treatment is based on optimizing public and environmental protection by defining an approach to wastewater treatment that uses best demonstrated available technology that is economically achievable (BDATEA), and capable of meeting regulatory requirements.

The chemical and radionuclide concentrations in leachate are calculated using a partitioning model that assumes that the ratio of the contaminant concentration in the solid phase to the contaminant concentration in the leachate is constant. These factors conservatively estimate the leachate characteristics. The radionuclide concentrations in wastewater are a combination of the leachate concentrations and the leachate volume, combined with the contact water and decontamination volumes. The contact water is assumed to have very low radionuclide concentrations because of the effects of daily ECM cover and water management practices within the disposal cell. Decontamination water is assumed to have the same radiological and chemical characteristics as the wastewater from the ECM. In the absence of quantitative information, non-radioactive waste constituents were developed from, information gathered from other sites and the expected characteristics of wastes to be disposed of in the NSDF. These values present a reasonable and conservative estimate of concentrations in wastewater such that the WWTP design is capable of treating wastewater to meet site-specific treatment targets.

Treated effluent will be monitored and confirmed that it meets treatment targets before release to East Swamp Wetland. Treated effluent from the WWTP will be released to an exfiltration gallery promote the exfiltration of treated water into the local groundwater regime; from here, small quantities of residual contaminants will migrate towards the East Swamp Stream. The East Swamp Stream feeds Perch Lake, which is connected to the Ottawa River through Perch Creek. Residual contaminants from the WWTP effluent will be most concentrated with the East Swamp Stream due to dilution in Perch Lake, Perch Creek and the Ottawa River. Doses to non-human biota exposed to the aquatic habitat of East Swamp Stream were calculated to provide a bounding estimate of potential exposure.

A comprehensive framework for assessing radiological exposure to Non-Human Biota is provided in the CSA Standard N288.6-12. Both aquatic and terrestrial species will be exposed to contaminated surface water and sediment in the East Swamp stream, Perch Lake, Perch Creek, and Ottawa River. As dilution will occur in the Perch Lake, Perch Creek and Ottawa River, exposure within the aquatic environment of the East Swamp stream is bounding during the period of leachate management system and WWTP operations. Doses to non-human biota were calculated based on the waterborne and airborne emissions from the ECM. It was conservatively assumed that all species would be exposed to a gamma dose rate of 10 microgray per hour (µGy/h), which is based on the dose constraint of 10 microsieverts per hour (µSv/h) at the NSDF fence line. The predicted doses to all indicator species of concern are below the dose benchmark values specified in CSA Standard N288.6-12. A complete description of the assessment to doses on non-human biota is provided in the Performance Assessment Report for the NSDF Project (CNL 2017), and summarized in Section 5.7.

Although there are no new or planned facilities other than the NSDF that may affect the Perch Lake Basin, many of the site's existing WMAs, including WMAs A and B and the LDA (which includes Reactor Pit 1, Reactor Pit 2 and the Chemical Pit) are also in this basin. Contaminants are transported via groundwater to nearby wetlands, including East Swamp, which will be the recipient water body for the NSDF wastewater. Contaminants released into the Perch Lake Basin migrate to Perch Creek from where they reach the Ottawa River, which is the ultimate receptor for all CRL discharges. The NSDF's contribution to potential effects on populations of non-human biota in the Perch Lake Basin does not result in unacceptable cumulative effects. Estimated doses resulting from historic contamination due to releases from WMAs and LDAs, fall below benchmark values for Perch Lake and Perch Creek. Potential contribution from the NSDF to exposure of aquatic species in East Swamp is less than 1% of the current levels of exposures.

For non-radiological constituents, surface water model scenarios were completed for a select group of constituents of potential concern (COPC) as defined in Section 5.4.2.7.1. Key elements of the COPC selection process included identifying those COPCs that were expected to change as a result of the NSDF Project, those with available guidelines, and those that were expected to be toxic to terrestrial organisms. The ten selected COPCs were aluminum, barium, cadmium, copper, iron, lead, manganese, mercury, phosphorus and zinc.

The predicted non-radiological concentrations for the COPCs were compared to effluent limits and to local background at the six water quality nodes (see Section 5.4.2.7.2, Tables 5.4.2-8 to Table 5.4.2-17). Note, comparison of treated effluent was to aquatic life guidelines as this provides a conservative assessment. The predicted concentrations of lead, phosphorus and zinc met their respective effluent limits and local background concentrations and as such were not retained for further consideration. The predicted concentrations of aluminum, barium, and mercury met their respective aquatic life guidelines; therefore, there are no anticipated risks to wildlife life due from these COPCs during the operations phase (Appendix 5.5-1). Overall, changes to

groundwater and surface water quality (and habitat quality) from the discharge of treated effluent are not predicted to affect the maintenance of self-sustaining and ecologically effective wildlife populations that overlap the RSA.

- **Leakage of leachate from the ECM during the post-closure phase (i.e., after Year 2400) from liner and cover failure as a result of normal evolution can cause changes to groundwater quality in the wetland and downstream surface water quality, which can affect wildlife survival and reproduction.**

Construction, operation, and closure activities of the ECM are designed to provide a stabilized waste array with the purpose of limiting settlement, and water infiltration. After facility closure, the primary pathway for unintended radionuclide releases from the completed phases of the ECM to the environment would be through the groundwater. The groundwater monitoring program for the operational phase will be continued during the initial period after facility closure but will gradually be reduced if no radionuclide or chemical constituent migrations are identified.

After the closure of all cells and following the decommissioning work, but prior to the end of the Institutional Control period (assumed to take place in the year 2400), both the liner and the engineered cover of the ECM will be within their 500-year design life. A small quantity of leachate will continue to be generated for a relatively short period of time after installation of engineered covers over all ECM disposal cells. The WWTP will continue to operate for as long as contaminated leachate is being generated.

During the post-closure phase, post-institutional control period (i.e., after year 2400) deterioration in the performance of engineered features of the ECM due to the effects of the environment on the engineered cover, base liner and other components of the containment is expected as part of normal evolution. The vegetative cover over the ECM will be replaced with plants that provide less efficient evapotranspiration, soil may begin to erode as a result of weathering and the engineered cover will begin to deteriorate. Eventually, it is assumed that the waste, having dried out during the post-closure period of Institutional Control, will rehydrate and become partially saturated due to infiltration of precipitation. At this time, one of two plausible scenarios may take place:

- **Leaching Through the Base Liner:** If the base liner fails at this time, then it will provide a pathway for the leachate to enter the groundwater. The rate at which contaminants move through the liner system and the groundwater flow system will in part be controlled by the solubility and sorption interactions that involve specific contaminants. If sufficiently mobile, the contaminants will eventually discharge to Perch Creek and thence to the Ottawa River.

- **Bathtub Effect Overflow Scenario:** If the base liner remains intact, then the infiltrating water will continue to be constrained by the ECM liner and berms. Water will enter the ECM at a rate determined by the degree of failure of the cover and percolate through the waste. Within confines of the berms the ECM will become fully saturated and leachate will discharge to surface at the lowest point of the berm. Depending on the rate of discharge the escaping leachate will infiltrate to the local groundwater flow system and may also flow overland to Perch Creek.

The final cover system will be constructed to promote the shedding of surface water to mitigate infiltration into the mound, and minimize leachate generation. This design also allows for minor differential settlement to occur while maintaining positive surface water drainage. In addition, the cover system design incorporates a series of shallow, trapezoidal, riprap-lined drainage channels that are designed to convey water at low velocity. Where slopes require, channels would include additional rock material to dissipate energy and prevent erosion or transport of materials. The perimeter road ditch will route the runoff around the ECM perimeter where it will then flow into discharge culverts to one of three stormwater ponds located outside the ECM perimeter road. These run-off controls are designed to minimize ponding of water into the closed ECM, erosion of the cover and underlying waste materials, destabilization of the ECM structure, and damage to access roads. Without controls, run-off could eventually lead to the creation of gullies and ravines that could compromise the integrity of the final cover system and/or the ECM structure. The ECM final grading and drainage plan also includes collection ditches along the top of the ECM berm road to collect side slope drainage.

Due to the presence of multiple barriers and the implementation of the above mentioned erosion controls, the likelihood of either scenario occurring before the end of the ECM design life (500 years) is very low. However, it was conservatively assumed, that one of these scenarios may occur immediately following the end of Institutional Control, which is assumed to take place in year 2400. Both of these release scenarios are considered to be “Normal Evolution” scenarios. A complete description of the assessment to doses on non-human biota is provided in the Performance Assessment Report for the NSDF Project (CNL 2017), and summarized in Section 5.7.

Doses to non-human biota, due to exposure from leakage through the base line or from the bathtub effect during the post-closure phase, were calculated based on the methods specified in CSA Standard N288.6-12. In addition, external gamma dose due to direct exposure to the waste is taken into account. It is conservatively assumed that all species are exposed to a dose rate of 10 µGy/h, which is the limiting criterion at the NSDF fence line. The external radiation is dominant compared to the waterborne pathway, although this is driven by conservatism in assumptions. The predicted doses to non-human biota for both scenarios are below dose benchmark values specified in CSA Standard N288.6-12. As such, changes to groundwater and surface water quality from the leakage of leachate from liner and cover failure as a result of normal evolution are not predicted to affect the maintenance of self-sustaining and ecologically effective vegetation communities and wildlife populations that overlap the RSA.

As described previously, for non-radiological constituents, surface water model scenarios were completed for a select group of COPCs as defined in Section 5.4.2.7.1. The predicted non-radiological concentrations for the COPCs were compared to effluent limits and to local background at the six water quality nodes (Section 5.4.2.7.2, Tables 5.4.2-8 to Table 5.4.2-17). The predicted concentrations of lead, phosphorus and zinc met their respective effluent limits and local background concentrations and as such were not retained for further consideration. The predicted concentrations of aluminum, barium, and mercury met their respective aquatic life guidelines; therefore, there are no anticipated risks to terrestrial VCs due to aluminum, barium and mercury at any assessed water quality node for these COPCs (Appendix 5.5-1).

Cadmium, copper, iron, and manganese had predicted concentrations greater than their respective aquatic life guidelines during the institutional control and post-institutional control periods of the Project, which follow the decommissioning of the WWTP. However, considering the conservative assumptions related to the non-radiological concentrations in the waste material and the conservative assumptions in the water quality modeling (Section 5.4.2), and considering that wastes will be required to meet the facility's Waste Acceptance Criteria (WAC), risks associated with these parameters and phases are not predicted to affect the maintenance of self-sustaining and ecologically effective wildlife populations that overlap the RSA.

5.6.5.2.3 Primary Pathways

Primary pathways advanced for further residual effects assessment and determination of significance are summarized by VC in Table 5.6.5-2. As a result of mitigation, the migratory bird VC will not be affected by any mortality-related pathways. Because several other VCs are migratory birds and changes in habitat availability and distribution will be addressed for these VCs, migratory birds as a group were not carried forward for further assessment.

Table 5.6.5-2: Interaction between Primary Pathways and Terrestrial Biodiversity Valued Components

Primary Pathway	Vegetation Communities	Migratory Birds	Canada Warbler	Eastern Whip-poor-will	Golden-winged Warbler	Bats	Blanding's Turtle
Vegetation clearing and grubbing during construction will result in the loss or alteration of existing vegetation and topographical features. This will cause losses of some vegetation communities, and potentially change wildlife habitat availability, use, and connectivity, and could influence wildlife abundance and distribution.	+	+	+	+	+	+	+
Sensory disturbance (i.e., lights, smells, noise, human activity, alteration of viewscape) can change wildlife habitat availability, use and connectivity (movement and behaviour), which can lead to changes in wildlife abundance and distribution.	-	+	+	+	+	+	+
Movement of heavy equipment and other vehicles on roads and through previously undeveloped / forested areas may cause injury or mortality to Blanding's turtle.	-	-	-	-	-	-	+
Installation and maintenance of perimeter fencing will potentially modify movement corridors for Blanding's turtle in the LSA which may increase their travel distances and thus increase the risk of injury/mortality on roads.	-	-	-	-	-	-	+

+ = primary pathway for this valued component; **-** = no interaction or secondary pathway for this valued component.

5.6.6 Residual Effects Assessment Methods

5.6.6.1 Residual Effects Analysis

The residual effects analysis for the Application Case describes the incremental changes caused by the NSDF Project from existing conditions. Residual effects are described for each of the measurement indicators identified in Section 5.6.2.2 for the primary pathways identified for each terrestrial biodiversity VC (Section 5.6.6.2.3), as follows:

- Changes in ecosystem availability were estimated quantitatively by calculating differences in the amount of different types of vegetation communities. For wildlife VCs, changes in habitat availability were estimated quantitatively by calculating differences in the amount of suitably habitat and qualitatively by considering potential changes in habitat use by wildlife (e.g., avoidance due to sensory disturbance).
- Changes in ecosystem distribution were estimated for the vegetation communities VC by qualitatively examining changes to the size and distribution of vegetation communities within the RSA and LSA. For wildlife VCs, changes in habitat distribution in the RSA and LSA were estimated by qualitatively evaluating the distribution of suitable wildlife habitat and considering wildlife VC movement, habitat connectivity and potential barriers to their dispersal.
- Changes in ecosystem condition (vegetation community VC) or survival and reproduction (wildlife VCs) were identified qualitatively and quantitatively using the results from changes in vegetation communities, and knowledge of potential changes in abundance from other NSDF Project components and activities (e.g., wildlife strikes with vehicles). Predictions of change were made using data collected in the RSA and the LSA, where possible, and supported by scientific literature.

The residual effects analysis uses a logical reasoning to describe anticipated changes to each measurement indicator caused by the NSDF Project. This narrative description of anticipated effects is the foundation for the residual effects classification presented in Section 5.6.7.3.

5.6.6.2 Prediction Confidence

The predicted residual effects are based on scientific inference and logical reasoning, which are associated with uncertainty. Consequently, a description of the level of confidence that can be assigned to the residual effect analysis was presented for each terrestrial biodiversity VC.

Primary factors affecting confidence in the predictions made in the terrestrial biodiversity assessment include:

- availability and accuracy of baseline data;
- accuracy of vegetation spatial data and inferences on habitat associations;
- level of understanding of the strength of primary pathways (i.e., mechanisms) in terms of the effects they are likely to have on each VC;
- level of certainty associated with the effectiveness of proposed mitigation, where applicable; and,
- level of understanding of the cumulative drivers of change in measurement indicators and associated effects on assessment endpoints.

Uncertainty in the assessment was managed by:

- reviewing historical and current data and relevant studies conducted in the study areas;
- conducting desktop studies to understand potential interactions between the proposed NSDF Project and terrestrial biodiversity, and supplementing with local and regional data, to the extent possible; and,
- comparing assessment results with relevant published literature to make inferences about ecological interactions and mechanisms of change.

Remaining uncertainty was primarily addressed by making assumptions that overestimated rather than underestimated potential effects of the NSDF Project (i.e., a precautionary assessment). This approach meant that when uncertainty was identified, the assessment was likely to overestimate predicted residual effects. For example, East Mattawa Road is an existing road that will be used as the main access road for the NSDF Project. The north and south ends of East Mattawa Road require upgrading; however, no or little additional clearing to widen and have sufficient clearance for operational needs is needed. East Mattawa Road was not mapped as “unclassified” in the FRI dataset, it was considered to be part of the forested polygon. Consequently, the amount of physical disturbance to vegetation communities from the NSDF Project was overestimated in these areas (as the FRI dataset used for calculating changes to vegetation communities would make it appear that the entire segment of East Mattawa Road within the SSA is a “new” disturbance to the forested land cover), providing a precautionary assessment.

5.6.6.3 Residual Effects Classification

Residual effects from the NSDF Project on each measurement indicator for each VC were classified according to the standard effects criteria described by The Agency (2015) and presented in Table 5.6.6-1.

Magnitude was not classified categorically (Table 5.6.6-1) because narrative or numeric quantification are more useful for unambiguously describing the effects of the NSDF Project for these VCs. Integrating context to understand the point at which an effect size is large enough to be important for a VC is directly linked to the self-sustaining and ecologically effective status of the population, and is therefore considered as part of the significance evaluation.

Table 5.6.6-1: Definitions of Effects Categories Used to Classify Predicted Residual Effects Terrestrial Biodiversity Valued Components

Criteria	Definition	Description
Direction	Direction relates to the “value” of the effect in relation to the environment.	■ Positive – net gain or benefit; effect is desirable ■ Neutral – no change compared with baseline conditions and trends ■ Negative – net loss or adverse effect; effect is undesirable
Magnitude	Magnitude is the intensity of the effect or a measure of the degree of change from existing (baseline) conditions expected to occur in the criterion.	Magnitude will be defined for each measurement indicator to reflect VC-specific characteristics

Table 5.6.6-1: Definitions of Effects Categories Used to Classify Predicted Residual Effects Terrestrial Biodiversity Valued Components

Criteria	Definition	Description
Geographic extent	Geographic extent refers to the spatial area over which an effect will occur/can be detected (distance covered or range).	■ Project footprint – effect is limited to the direct physical disturbance from the NSDF Project (i.e., SSA) ■ Local – the effect is confined to the LSA ■ Regional – the effect extends beyond the LSA boundary, but is confined within the RSA ■ Beyond regional – the effect extends beyond the RSA boundary
Duration/ reversibility	■ Duration is the period of time over which the environmental effect will be present. The amount of time between the start and end of an activity or stressor (which relates to project development phases), plus the time required for the effect to be reversed. Duration and reversibility are functions of the length of time a criterion is exposed to activities. ■ Reversibility is an indicator of the potential for recovery of the criterion from an effect. Reversible implies that the effect will not influence the criterion at a future predicted period in time. For effects that are permanent, the effect is determined to be irreversible.	■ Short-term – the effect is reversible before the end of construction ■ Medium-term – the effect occurs during construction and/or operation and is reversible soon after operation begins ■ Long-term – the effect occurs during construction and/or operation and persists into closure, but is reversible ■ Permanent – the effect occurs during construction and/or operation and is irreversible
Frequency	Frequency refers to the occurrence of the environmental effect over the duration of the assessment. Discussions on seasonal considerations are made when they are important in the evaluation of the effect.	■ Infrequent – the effect is expected to occur rarely ■ Frequent – the effect is expected to occur intermittently ■ Continuous – the effect is expected to occur continually
Likelihood	Likelihood is a measure of the probability that an activity will result in an environmental effect.	■ Unlikely – the effect is not likely to occur ■ Possible – the effect may occur, but is not likely ■ Probable – the effect is likely to occur ■ Certain – the effect will occur

5.6.6.4 Determination of Significance

For each terrestrial biodiversity VC, a determination of significance was made based on an assessment of existing cumulative effects of previous and existing developments described in the Base Case. This classification provides context from the Base Case to which incremental changes in the Application Case are added. The addition of the incremental effects of the NSDF Project are described and classified according to the methods outlined Sections 5.6.6.1 and 5.6.6.3, respectively.

Future beyond regional disturbance factors such as climate change have the potential to adversely affect vegetation communities and populations of wildlife VCs that overlap with the RSA. Therefore, a determination of significance was also made based on the cumulative effects of previous and existing developments,

the incremental effect of the NSDF Project, and a qualitative consideration of future, beyond regional disturbance factors (e.g., climate change).

Significance was determined based on cumulative effects because the effects of a single project infrequently cause an ecologically significant effect on their own (McCold and Saulsbury 1996), and many environmental effects of primary concern are cumulative (Canter and Ross 2010). Therefore, whether vegetation communities or populations of wildlife VCs would remain self-sustaining and ecologically effective was assessed considering the cumulative effects of previous and existing developments in combination with the NSDF Project (i.e., Application Case). If a significant effect was identified for the Application Case, the incremental contribution of the NSDF Project to the significant effect was clearly described.

Significance was predicted as a binary response, with effects classified as significant or not significant. Residual effects were determined to be significant if a VC is expected to no longer be: (1) self-sustaining, or (2) ecologically effective. Specifically:

- A vegetation community or wildlife VC population was considered to be no longer self-sustaining where residual effects were expected to place the vegetation community or abundance of a wildlife VC, whether an open or closed population, on a declining trajectory that is not predicted to recover or stabilize. Part of being self-sustaining, in this context, was that a vegetation community or wildlife VC population that stabilizes at a lower abundance is not expected to be extirpated because of unrelated stochastic events. Another part of being self-sustaining was the assumption that no additional mitigation or management actions beyond the proposed NSDF Project mitigation strategies and existing management strategies in the region would be required. Residual effects that are considered to be not significant could result in either no change, stabilization at lower abundance, stabilization at higher abundance, or a temporary decline followed by recovery. Where vegetation communities or wildlife populations remain stable, fragmentation effects that cause vegetation communities or wildlife populations to become isolated or substantially disconnected (e.g., severely reducing or eliminating gene flow and/or demographic rescue within one regional or meta-population or between two or more local populations) may also be considered significant.
- A vegetation community or wildlife VC population that has lost important ecological function would also result in determination of a significant adverse effect, regardless of its self-sustaining status. Ecological function can be lost, even when a vegetation community remains abundant, if the composition of that community is altered. For wildlife VCs, loss of ecological function occurs when a population can no longer perform its ecological role, such that it might trigger ecological changes that result in degraded or simplified ecosystems (Soulé et al. 2003). The potential to lose ecological function is more common for highly interactive wildlife VCs that have important ecological effects on other species, such as predators or ecosystem engineers (i.e., organism that creates, considerably modifies, maintains or destroys a habitat; Soulé et al. 2003).

The approach to determining the significance of residual effects for each VC incorporated the concepts of resilience and adaptability using the reasoned narrative provided in the residual effects assessment. Although the determination of significance was informed by the VC for characterizing residual effects, the interaction between ecological context from the Base Case and the magnitude, duration, and geographic extent of the interacting residual effects were the most important factors. Provincial and federal standards, guidelines, and objectives were considered, where available, and integrated into the reasoned narrative.

If uncertainty was high about where a threshold for a significant effect would occur in the range of cumulative change for the Application Case, and if the residual effect could be assessed as either significant or not significant, a precautionary approach was applied and the effect was identified as significant. The greater the uncertainty, the earlier a significant effect would be identified on the continuum of cumulative change. Effects determined significant because of high uncertainty around undefined true thresholds were clearly identified as such, and additional follow-up actions to reduce uncertainty were proposed (Section 5.6.9).

Adding to the challenges of understanding complex systems is the difficulty of forecasting a future that may be outside the range of observable baseline environmental conditions (Walther et al. 2002). For example, climate change models predict an increase in average global temperatures (Huff and Thomas 2014); however, the effect of these changes on ecosystem processes is uncertain (Deser et al. 2010; Walther 2010). Predicting how an ecosystem or an individual species will cope with climate change is difficult and many scenarios are possible (Dawson et al. 2011).

Climate change was addressed in this assessment using a precautionary approach. For example, climate change may have different effects on plant species abundance and distribution through shifts in temperature, precipitation, fire and insects, which can alter wildlife populations (Huff and Thomas 2014). If one scenario was much more likely than another, the assessment considered the most likely scenario. However, if uncertainty was high, the assessment considered a precautionary outcome for each VC.

5.6.7 Residual Effects Assessment Results

5.6.7.1 Vegetation Communities

5.6.7.1.1 Residual Effects Analysis

Ecosystem Availability

The incremental effect of the NSDF Project on ecosystem availability is summarized in Table 5.6.7-1. At the RSA scale, the changes to ecosystem availability represents a total permanent loss of 0.8% of forested ecosystems, primarily of second-growth, mature, mixed forest with high poplar content and snag presence. A somewhat greater proportional loss of the total coniferous forest coverage in the RSA (at 2%) is predicted. Coniferous forest stands are relatively rare in the RSA and the effects of the NSDF Project on coniferous forests is due to the predicted loss of one Norway spruce plantation stand and a portion of another coniferous forest stand.

There will be a total loss of 30 ha of forested ecosystems as a result of the NSDF Project (i.e., in the SSA). The remaining area affected within the SSA is unclassified / already anthropogenically altered land cover that will permanently retain the same classification once the NSDF Project has been constructed. Avoidance undertaken during the NSDF Project design means that wetland ecosystems availability remains unchanged. At the LSA scale, the permanent loss of 30 ha of forest translates to 14.8% of forested ecosystems.

Table 5.6.7-1: Changes to Availability of Vegetation Communities in the Application Case

Vegetation Community	Regional Study Area				Local Study Area			
	Base Case [ha]	Application Case [ha]	Change in Area [ha]	Percent Change[a] [%]	Base Case [ha]	Application Case [ha]	Change in Area [ha]	Percent Change[a] [%]
Mixed Forest	1,930	1,906	-24	-1.2	66	42	-24	-36
Deciduous Forest	643	640	-2	-0.3	5	3	-2	-46
Coniferous Forest	199	195	-4	-2.0	5	1	-4	-85
Wetland	522	522	0	0.0	61	61	0	0.0
Flooded	1	1	0	0.0	0	0	0	0.0
Unclassified (cleared)	268	26	0	0.0	26	26	0	0.0
Total Aquatic Habitat:	274	274	0	0.0	41	41	0	0.0
Gaps / Slivers:	16	16	0	0.0	0	0	0	0.0
Total	**3,853**	**3,823**	**-30**	**-0.8**	**203**	**173**	**-30**	**-15**

Note: Some numbers are rounded for presentation purposes. Therefore, it may appear that the totals do not equal the sum of the individual values.

a) The total percent change is calculated relative to the total area and therefore this value will not equal the sum of the individual values.

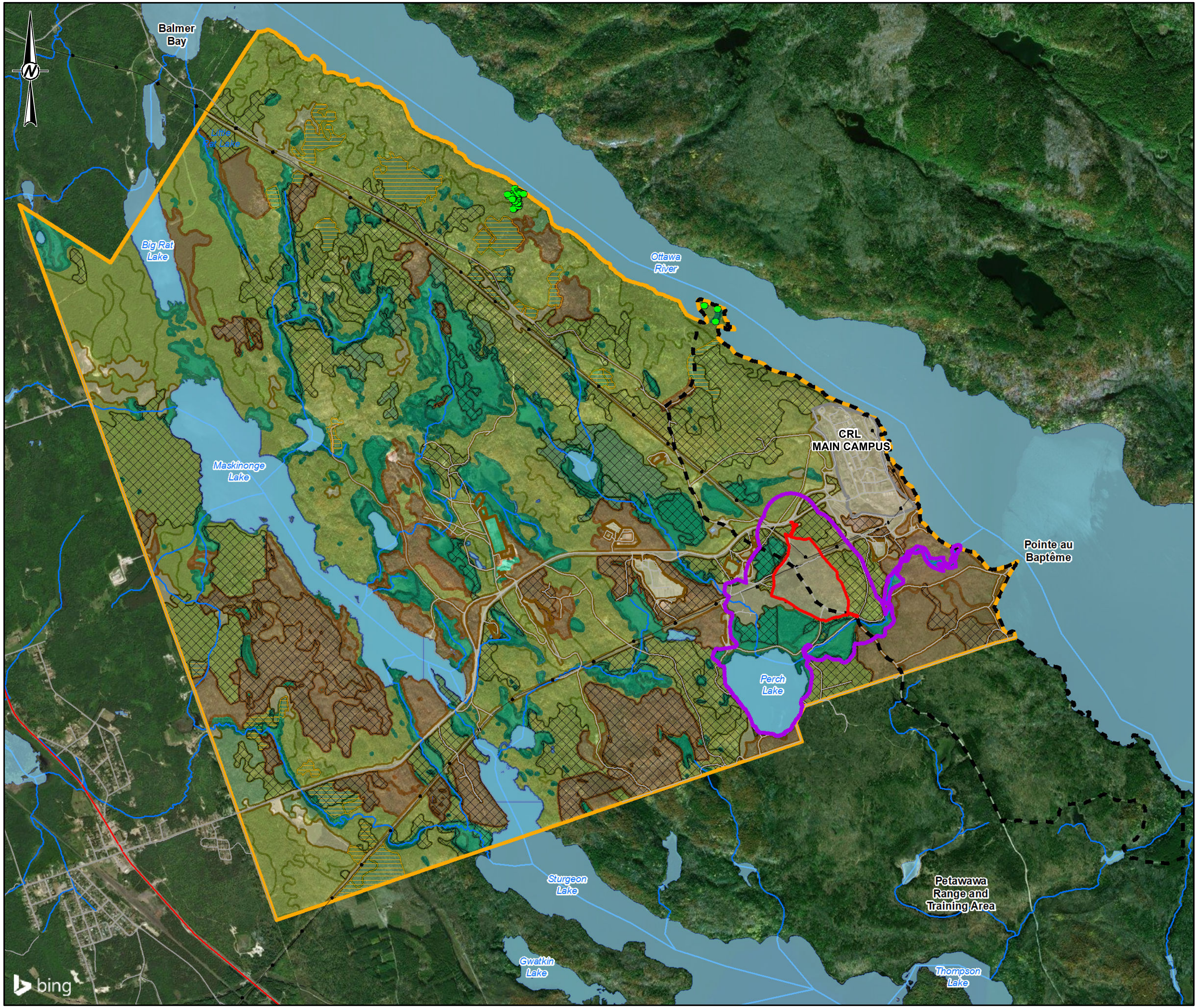
ha = hectare; % = percent.

Ecosystem Distribution

At the RSA scale, the NSDF Project creates a relatively minor gap in existing forest coverage (0.8% change in coverage with a corresponding small degree of change to distribution). Distribution of vegetation communities within the RSA in the Application Case are presented in Figure 5.6.7-1. The location of the NSDF Project is within the southeast corner of the RSA that already contains the highest level of anthropogenic disturbance and activity, leaving the northern two-thirds of the RSA still largely undisturbed.

Distribution of vegetation communities within the LSA and SSA at Application Case are presented in Figure 5.6.7-2. At a local level, the NSDF Project footprint represents a relatively larger gap in forested ecosystems, a span of approximately 930 m from north to south, and 640 m from east to west (14.8% change in coverage). Ecosystem processes, and in particular, the use of ecosystems by the wildlife VCs considered, are at a broader scale and are less likely to be disturbed as a whole, at this local scale. The range of these species is beyond the LSA boundary – which does not have an ecologically functional basis, and is primarily defined by the footprint of the NSDF Project. Fragmentation of forested ecosystems is a concern if it reaches a threshold beyond which interior and area-sensitive species can tolerate. With the high degree of forest cover remaining on the landscape, it is highly unlikely the forest clearing associated with the NSDF Project will represent a level of fragmentation that goes beyond this threshold. The forested ecosystems within the SSA were already fragmented by East Mattawa Road, which bisects the forested area, and two transmission corridors, which criss-cross the northern portion of the forested area; therefore, the actual “new” edge creation is limited, but the size of the gap between the edges is increased.

This page intentionally left blank



LEGEND

- HIGHWAY
- ROAD
- TRANSMISSION LINE
- NATURAL GAS PIPELINE
- RIVER/STREAM
- WATERBODY
- CRL MAIN CAMPUS
- WASTE MANAGEMENT AREA (WMA)[1]
- REGIONAL STUDY AREA (CRL PROPERTY)
- LOCAL STUDY AREA
- SITE STUDY AREA (NSDF PROJECT SITE)
- NORTH-SOUTH 2002 STUDY AREA

VEGETATION COMMUNITIES

- MIXED FOREST
- DECIDUOUS FOREST
- CONIFEROUS FOREST
- WETLANDS
- FLOODED AREA
- UNCLASSIFIED (CLEARED)
- MATURE FOREST STAND
- PLANTATION

SARA LISTED PLANT SPECIES OBSERVATION

- BUTTERNUT OBSERVATION

1 0 1
1:35,000 KILOMETRES

NOTE(S)
1. LIQUID DISPOSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.

REFERENCE(S)
1. BASEDATA MNRF 2016 AND CANVEC 2016
2. IMAGERY: © 2017 DIGITALGLOBE IMAGE COURTESY OF USGS EARTHSTAR GEOGRAPHICS SIO © 2017 MICROSOFT CORPORATION
3. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE18N

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
VEGETATION COMMUNITIES AVAILABILITY AND DISTRIBUTION IN THE RSA – APPLICATION CASE

CONSULTANT

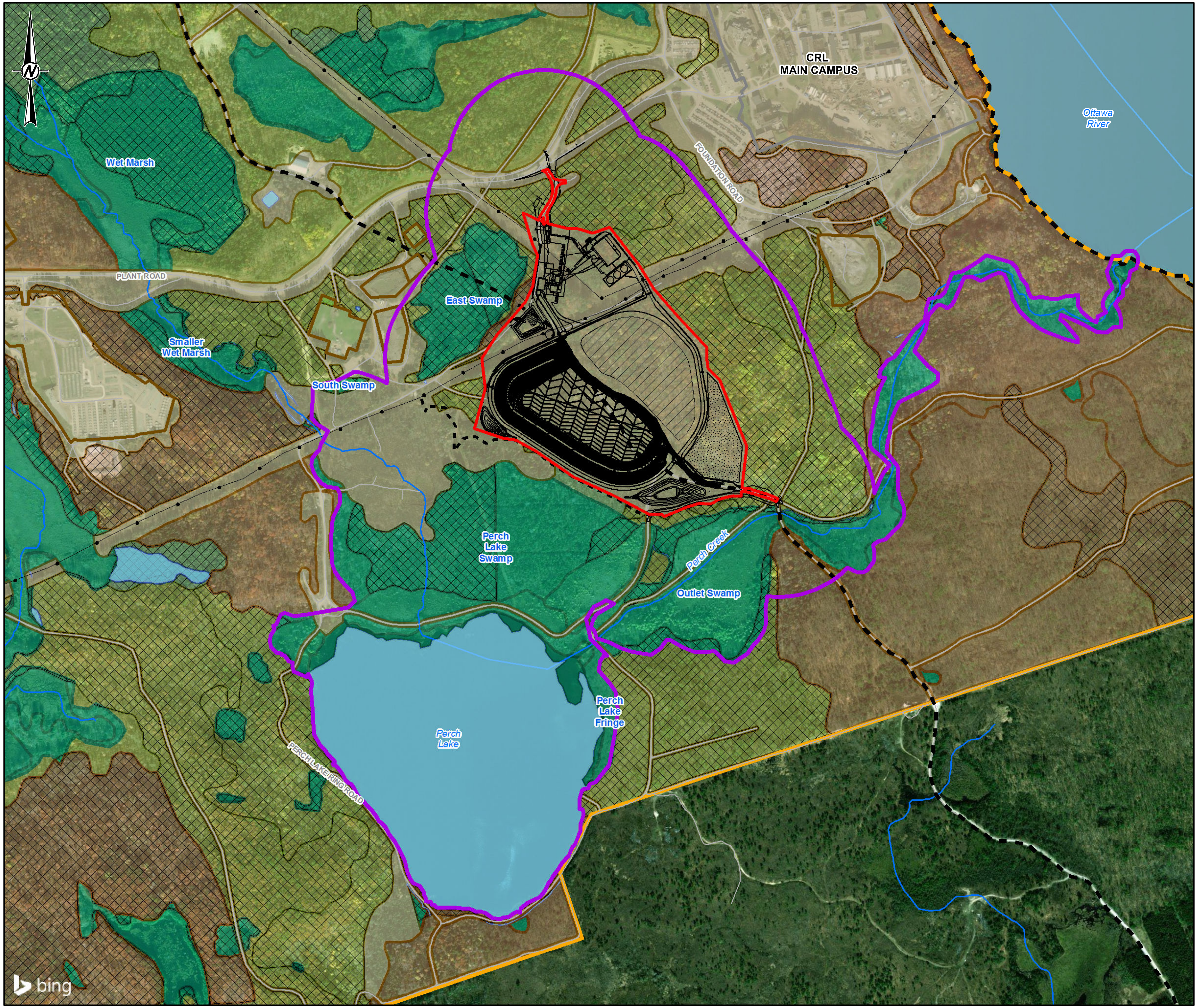
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	LH
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.6.7-1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:
25mm

This page left intentionally blank



LEGEND

- HIGHWAY
- ROAD
- TRANSMISSION LINE
- RIVER/STREAM
- WATERBODY
- FENCE
- INFRASTRUCTURE
- LAYDOWN AREA
- STOCKPILE
- CRL MAIN CAMPUS
- WASTE MANAGEMENT AREA (WMA)
- REGIONAL STUDY AREA (CRL PROPERTY)
- LOCAL STUDY AREA
- SITE STUDY AREA (NSDF PROJECT SITE)
- NORTH-SOUTH 2002 STUDY AREA

VEGETATION COMMUNITIES

- MIXED FOREST
- DECIDUOUS FOREST
- CONIFEROUS FOREST
- WETLANDS
- FLOODED AREA
- UNCLASSIFIED (CLEARED)
- MATURE FOREST STAND
- PLANTATION

FOREST UNIT CODES:

Forest Unit	Description
MWUS	Mixed Uniform Shelterwood
PWUS	White Pine Uniform Shelterwood
SFUS	Spruce - Fir Uniform Shelterwood
INTCC	Intolerants Clear Cut
ORUS	Red Oak

FOREST COVER SPECIES CODES:

FRI Code	Tree Species	Coniferous (C) or Deciduous Species (D)
Bf	Balsam Fir (Abies balsamea)	C
Bw	Dwarf White Birch (Betula minor) or Paper Birch (B. papyrifera)	D
By	Yellow Birch (B. alleghaniensis)	D
La	American Larch (Tamarack) (Larix laricina)	C
Ms	Red Maple (Soft Maple) (Acer rubrum)	D
Or	Northern Red Oak (Quercus rubra)	D
Po	Poplar species (Populus sp.)	D
Pr	Red Pine (Picea resinosa)	C
Pw	Eastern White Pine (Pinus strobus)	C
Sp	Spruce species (Picea sp.)	C

250 0 250

1:10,000 METRES

NOTE(S)

1. LIQUID DISPOSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.

REFERENCE(S)

1. BASEDATA MNRF 2016 AND CANVEC 2016
2. IMAGERY: © 2010 DIGITALGLOBE IMAGE COURTESY OF USGS EARTHSTAR GEOGRAPHICS SIO © 2017 MICROSOFT CORPORATION
3. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE18N

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
VEGETATION COMMUNITIES AVAILABILITY AND DISTRIBUTION IN THE LSA AND SSA – APPLICATION CASE

CONSULTANT

Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	LH
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.6.7-2

This page left intentionally blank

Ecosystem Condition

At the regional scale, the NSDF Project will create a minor change in ecosystem condition with regard to mature forest cover (a loss of 2%; Table 5.6.7-2). At the local scale, the NSDF Project will have a larger relative effect (reduction in 42% of available mature forest cover) and result in a permanent conversion of primarily mature forest to road and/or turf-grass. The NSDF Project will create a permanent change to ecosystem condition from forested habitat to turf-grass habitat, with low value for terrestrial biodiversity. Moreover, terrestrial wildlife will be excluded from the NSDF Project footprint by a six foot high chain link perimeter fence that will remain through post-closure.

Table 5.6.7-2: Changes to Ecosystem Condition (as measured by Mature Forest Cover) in the Application Case

Forest Structural Stage	Regional Study Area				Local Study Area			
	Base Case [ha]	NSDF Project Case [ha]	Change in Area [ha]	Percent Change [%]	Base Case [ha]	NSDF Project Case [ha]	Change in Area [ha]	Percent Change [%]
Pre-sapling	31	31	0	0	0	0	0	0
Sapling	53	53	0	0	0	0	0	0
Immature	1,618	1,614	-4	0	13	9	-4	-31
Mature	1,070	1,044	-26	-2	63	37	-26	-42
Old	0	0	0	0	0	0	0	0

5.6.7.1.2 Prediction Confidence

Confidence in description of Base Case ecosystem availability, distribution and condition is tempered by reliance on primarily air-photo interpreted mapping – this potential for error is highlighted by the discrepancy in classification of a stand of one forest ecosystem type from North-South 2002 project in one portion of the SSA. The North-South Environmental survey work in 2002 classified the forested area within the north portion of the SSA, north of the east-west transmission line ROW, and straddling the north-south transmission line ROW, as white pine / red pine forest. The FRI data for the site has this area mapped as a poplar / yellow birch / red oak deciduous forest stand on the west side of the north-south transmission line ROW (which is inconsistent with the North-South report) but white pine / poplar / red pine on the east side of that ROW (which is consistent; Figure 5.6.7-2).

The FRI dataset also did not contain some common attributes that are used to assign ecosystem condition, including the year of origin for forest stands. The dataset used only provided the attribute of "age", and there was no date for the GIS spatial dataset available, meaning there may be some discrepancy in true forest stand ages relative to what was used in the assessment – with the degree of discrepancy widening depending on the age of the FRI dataset used.

Because of the lack of recent, ground-based surveys, the presence or absence of regionally- or provincially-rare vegetation species within areas to be disturbed cannot be determined. There is only one SARA-listed plant species that has been recorded in the RSA and could occur within the SSA: butternut (see Figure 5.6.4-1). However, this species does not have a high likelihood of occurring within the SSA due to the lack of suitable habitat and location of the RSA (but outside of the LSA) which is north of the current northern range extent (Appendix 5.6-1). Butternut

located at CRL are associated with an old homestead. Some regeneration was noted in one patch during surveys, but it was always in close proximity to the parent trees that were associated with the old homestead.

In all cases where there was the opportunity to be more conservative / precautionary in the assessment of effects on vegetation communities, decisions were made to achieve conservatism (e.g., use of modified age categories for forest unit structural age class definition so that stands that should be identified as mature or old based on leading tree species, specifically poplar, were identified as such).

Despite acknowledged deficiencies in reliance on desktop derived data, the vegetation communities to be removed as a result of the NSDF Project are not unique on the regional landscape. The FRI data for the SSA also generally corresponds to the findings of the Golder biologist that conducted a reconnaissance-level visit in 2016. Overview level review of Google Earth imagery has also confirmed general agreement with existing levels of forest cover and general composition.

Regardless of some level of uncertainty on exact stand composition, particularly in other areas of the RSA that were not visited during the site reconnaissance, the prediction of effects on the physical losses of vegetation communities has high confidence as the significance determination is primarily based on accurately quantifiable spatial changes to the landscape.

5.6.7.1.3 Residual Effects Classification

Vegetation communities in the RSA at Base Case are considered to be within the limits of resilience and adaptive capacity to changes in availability, distribution and composition. After calculating changes from the NSDF Project, the composition of vegetation communities remain common and well distributed in the RSA. An estimated 99% of non-disturbed vegetation communities (i.e., the forested stands and wetlands) present in the Base Case will remain intact in the Application Case. Moreover, the implementation of appropriate invasive species control in keeping with best management practices such as the OMNR Forest Management Guide for Conserving Biodiversity at the Stand and Site Scales (OMNR 2010b) will reduce the potential for invasive species to colonize vegetation communities adjacent to the NSDF Project. The most sensitive vegetation communities in the RSA (wetlands) will not be physically disturbed by the NSDF Project; there is no loss of wetlands within the SSA.

A summary of the classification of incremental adverse effects of the NSDF Project on vegetation communities in the Application Case is provided for each measurement indicator in Table 5.6.7-3. Residual effects were described after the implementation of effective mitigation, and summarized according to direction, magnitude, geographic extent, duration/reversibility, frequency/timing, and likelihood of the effect occurring following the methods described in Section 5.6.6.1. Effective implementation of mitigation summarized in Section 5.6.5.2 is expected to reduce the magnitude and duration of residual effects on vegetation communities.

Residual effects on the availability and distribution of vegetation communities resulting from the NSDF Project are predicted to be negative, resulting in a loss of 0.8% of forested communities in the RSA and 14.8% in the LSA. Construction of the NSDF Project will permanently remove forested vegetation communities and the direct effects of the changes will be confined to the NSDF Project footprint. Effects on vegetation community condition (e.g., species abundance and richness) are certain with regard to the permanent change in composition from largely undisturbed mature forest to heavily maintained turf-grass, but less certain due to the effectiveness of mitigation measures to avoid intrusion into adjacent forest and wetland edges by invasive species. For the purposes of this assessment, changes to all three indicators are assumed to be irreversible for vegetation communities affected by the NSDF Project footprint. Although reclamation of the NSDF Project footprint will be

completed, for the purposes of terrestrial biodiversity and vegetation communities specifically, conversion of a largely undisturbed, mature forested area to a permanently fenced, turf-grass habitat that is highly modified (i.e., mown, fertilized, and maintained as tree-free to avoid the disruption of roots to the cover structure) eliminates the applicability of reclamation as a means to reduce the level of residual effects.

Table 5.6.7-3: Classification of Residual Effects on Vegetation Community Indicators in the Application Case

Indicator	Characteristic	Rating/Effect Size
Ecosystem Availability	Direction	Negative
	Magnitude	Loss of 30 ha of forested communities (0.8% of the RSA Base Case; 14.8% of the LSA Base Case)
	Geographic Extent	Project Footprint
	Duration/Reversibility	Permanent/Irreversible
	Frequency/Timing	Continuous
	Likelihood	Certain
Ecosystem Distribution	Direction	Negative
	Magnitude	Changes to the distribution of vegetation communities primarily affects mixed forests and creates a localized fragmentation and distribution of this community type. However, East Mattawa Road and the two hydroelectric corridors already create three linear breaks in the distribution of forested communities in the SSA. In addition, these mixed forest communities remain well-connected in the majority of the RSA; this change in distribution only occurs within the southeast corner of the RSA that is already affected by anthropogenic activity and disturbance, and the remaining largely undisturbed areas are left unmodified by the NSDF Project. There will be no fragmentation of the wetlands, which are the most sensitive vegetation community.
	Geographic Extent	Project Footprint
	Duration/Reversibility	Permanent/Irreversible
	Frequency/Timing	Continuous
	Likelihood	Certain
Ecosystem Condition	Direction	Negative
	Magnitude	Conversion of the Base Case vegetation community composition from largely forested to turf-grass. Permanently affects the condition of a 30 ha area that is comprised primarily of mature forest under existing conditions. Edge effects during operations may alter adjacent vegetation community richness.
	Geographic Extent	Local
	Duration/Reversibility	Permanent /Irreversible
	Frequency/Timing	Continuous
	Likelihood	Certain (change to ecosystem condition) / Possible (introduction of invasive species)

5.6.7.1.4 Determination of Significance

The combined effects of past and present activity have altered vegetation communities in the RSA. Historically, forest composition and structure in the Georgian Bay Ecoregion was primarily driven by wildfire, insect outbreaks, and disease. Within the RSA, active fire suppression combined with a lack of timber harvest since the 1940s has resulted in a high concentration of forested habitats, including mature forests (Section 5.6.5.1). The forest age class with highest coverage in the RSA in the Base Case is the immature seral stage at 1618 ha (42%), with mature forest having second highest coverage, at 1070 ha (27.8%). The LSA has the reverse, with mature forest at higher coverage (63 ha and 31% total area coverage) than immature forest (12.8 ha or 6.3%).

The relatively high coverage of older seral stages of forest cover within the RSA, as well as relatively high spatial coverage of wetlands and other aquatic habitat types, combines to create an area of high value for terrestrial biodiversity. This is especially true relative to areas surrounding the RSA that are more affected by forestry, farming, and industrial disturbance. These forested ecosystems are interspersed and relatively abundant, wetlands and natural vegetation communities are well distributed and connected in the RSA in the Base Case. Therefore, the combined evidence considered for ecosystem availability, distribution, and condition indicates vegetation communities are currently self-sustaining and ecologically effective in the Base Case.

Because vegetation communities in the RSA are abundant, well connected, and in good condition, they are expected to have the capacity to adapt and be resilient to existing natural and human-related disturbances. The NSDF Project will result in a permanent loss of 30 ha of forest, most of which is mature (2.0% of the Base Case RSA; 42% of the Base Case LSA). This is predicted to create small, negative changes to vegetation community availability, distribution, and condition. However, although the loss of forest is permanent, these forest types are abundant in the RSA and incremental loss of forested vegetation communities from the NSDF Project is predicted to have little influence on ecological structure and function; 99% of undisturbed forested and wetland ecosystems present in the Base Case are predicted to remain in the Application Case. The NSDF Project will also not physically alter the wetlands, which are most sensitive vegetation community within the RSA.

With effective implementation of the mitigation summarized in Table 5.6.5-1, the incremental contribution of the NSDF Project to combined effects from previous and existing development on vegetation communities in the RSA is not expected to change the self-sustaining and ecologically effective status of this VC. Consequently, effects on vegetation communities in the Application Case are predicted to be not significant.

5.6.7.2 Canada Warbler

5.6.7.2.1 Residual Effects Analysis

Habitat Availability

The NSDF Project is estimated to remove 25 ha of suitable breeding habitat for Canada warbler (Table 5.6.7-4). Sensory disturbance during construction, operation and closure phases may indirectly reduce Canada warbler habitat availability in the LSA through avoidance. Noise levels greater than 50 decibels (dB) can negatively affect birds (ECCC 2016a). Canada warblers may avoid otherwise suitable habitat in areas where NSDF Project activities create noise levels greater than 50 dB.

Table 5.6.7-4: Changes to Canada Warbler Breeding Habitat Availability in the Application Case

Habitat Suitability	Regional Study Area				Local Study Area			
	Base Case [ha]	Application Case [ha]	Change in Area [ha]	Percent Change [%]	Base Case [ha]	Application Case [ha]	Change in Area [ha]	Percent Change [%]
Suitable	1,701	1,676	-25	-1.5	119	94	-25	-20.9
Unsuitable	2,152	2,177	25	1.2	84	109	25	29.4

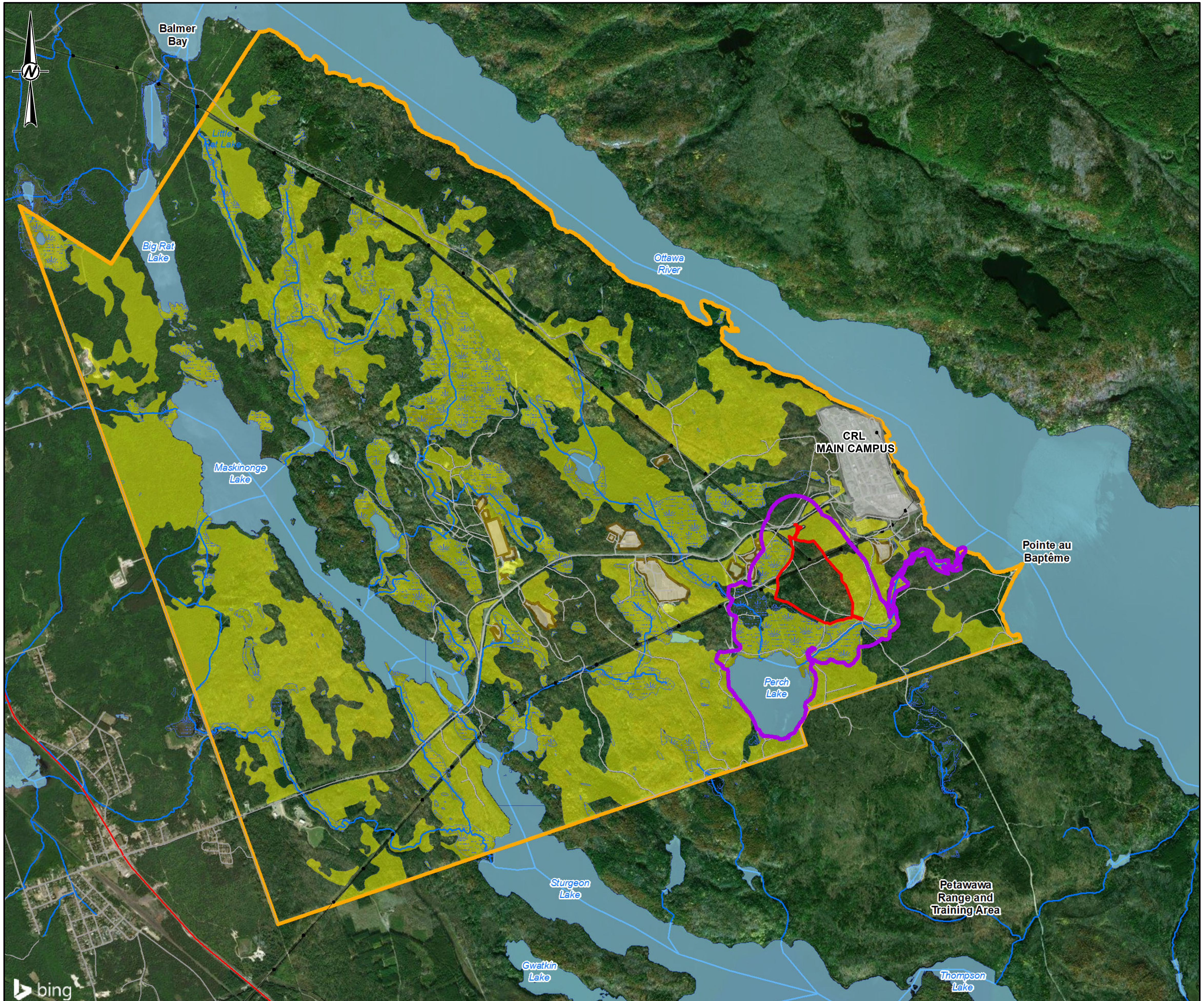
ha = hectare; % = percent.

Effects on Canada warbler from changes to habitat availability are certain because the NSDF Project will cause a direct loss of suitable breeding habitat; indirect habitat loss from avoidance due to sensory disturbance is probable. Changes to habitat availability from habitat loss are permanent because the ECM will remain deforested in perpetuity. Changes due to avoidance is expected to occur continuously over the long-term (reversible after operations is completed). Canada warblers that occupy areas near the NSDF Project footprint may become acclimatized to sensory disturbance from the NSDF Project and may use suitable habitats near the NSDF Project footprint within one to three years after construction is completed.

Habitat Distribution

Canada warblers are highly mobile and capable of moving around or over the NSDF Project infrastructure. Forest clearing in the NSDF Project footprint is approximately 30 ha. Canada warblers may perceive this area of forest clearing as a barrier to movement (Desrochers and Hannon 1997; St. Clair et al. 1998); however, the land around the NSDF Project footprint will remain in natural cover, which is primarily forest, allowing individuals to move around the NSDF Project during transit. The NSDF Project footprint represents a large portion of the LSA (14.8%) and is expected to affect Canada warbler movement, with individuals travelling along the perimeter of the LSA more frequently in the Application Case than in the Base Case, as a result of the NSDF Project footprint being located in the centre of the LSA (Figure 5.6.7-4). The development of the NSDF Project is unlikely to have a measurable effect on Canada warbler habitat distribution and movement in the RSA given the small size of the NSDF Project footprint and its location in the southeastern portion of the RSA where most existing human disturbance is concentrated (Figure 5.6.7-3).

This page intentionally left blank



LEGEND

- HIGHWAY
- ROAD
- TRANSMISSION LINE
- NATURAL GAS PIPELINE
- RIVER/STREAM
- WATERBODY
- WETLAND
- CRL MAIN CAMPUS
- WASTE MANAGEMENT SITES (WMA)[1]
- REGIONAL STUDY AREA (CRL PROPERTY)
- LOCAL STUDY AREA
- SITE STUDY AREA (NSDF PROJECT SITE)
- CANADA WARBLER HABITAT

1 0 1
1:35,000 KILOMETRES

NOTE(S)
1. LIQUID DISPOSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.

REFERENCE(S)
1. BASEDATA MNRF 2016 AND CANVEC 2016
2. IMAGERY: © 2017 DIGITALGLOBE IMAGE COURTESY OF USGS EARTHSTAR GEOGRAPHICS SIO © 2017 MICROSOFT CORPORATION
3. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE18N

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
CANADA WARBLER HABITAT AVAILABILITY AND DISTRIBUTION IN THE RSA – APPLICATION CASE

CONSULTANT

Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	KS
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.6.7-3

This page left intentionally blank

NOTE(S)
1. LIQUID DISPOSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.

REFERENCE(S)
1. BASEDATA MNRF 2016 AND CANVEC 2016
2. IMAGERY: © 2010 DIGITALGLOBE IMAGE COURTESY OF USGS EARTHSTAR GEOGRAPHICS SIO © 2017 MICROSOFT CORPORATION
3. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE18N

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
CANADA WARBLER HABITAT AVAILABILITY AND DISTRIBUTION IN THE LSA AND SSA – APPLICATION CASE

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	KS
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.6.7-4

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm

S:\Clients\Canadian_Nuclear_Laboratories\NSDF\99_PROJ\1547525_NSDF_EIS\40_PROD\0009_EIS_Section_5.6\Section_5.6_Terrestrial\1547525-0009-RT-0019.mxd

This page left intentionally blank

Survival and Reproduction

Site clearing for the NSDF Project is not predicted to cause Canada warbler mortality. Adult Canada warblers are mobile and can avoid interactions with activities that could result in direct mortality, and mitigation will be implemented to avoid nest loss (Section 5.6.5.2.1).

The loss of breeding habitat may affect reproductive success if individuals are displaced or return to breeding grounds to find habitat removed, and subsequently are unable to establish a new territory or establish a territory in lower quality habitat. However, potentially suitable nesting habitat is broadly available in the RSA.

Sensory disturbance, such as noise from construction of the NSDF Project, may potentially reduce reproductive success and survival in the LSA by raising stress levels and interfering with communications (e.g., reducing ability to hear approaching predators or intraspecific vocalizations; Ortega 2012). Thus, the carrying capacity of the LSA and RSA during the Application Case may be reduced relative to conditions at Base Case.

5.6.7.2.2 Prediction Confidence

The residual effects assessment for Canada warbler is based on a good understanding of this species ecology and tolerance to anthropogenic activities, and a moderate understanding of threats to the persistence of the species. There is some uncertainty concerning the Canada warbler population in the RSA because few quantitative data are available. Some uncertainty also exists in the accuracy of the mapping layer used to predict habitat availability, which was defined by relatively coarse vegetation community categories that did not always capture detailed habitat preferences. Moreover, the age of forested stands in the RSA may be underestimated; although information on stand age was available in the FRI data, the dates associated with polygon delineation were not provided with the dataset, and therefore, stand age could not be corrected based on the age of the dataset. Finally, the mapping could not be validated due to the limited amount of ground-truthing data available. This assessment dealt with uncertainty in map accuracy by making precautionary assumptions about habitat availability and occupancy in the study areas, and most likely overestimated the amount of habitat loss and reduction in carrying capacity.

There is a high level of uncertainty associated with the future population status of Canada warbler in Canada. Evidence suggests that populations are declining across the species' range, including in Ontario. If the declining population trend is not reversed or accelerates over the next decade, then Canada warbler may be up-listed from threatened to endangered. Critical habitat for Canada warbler is anticipated to be identified and one or more action plans will be developed for this species by 2021 (Environment Canada 2016b).

5.6.7.2.3 Residual Effects Classification

A summary of the classification of incremental adverse residual effects of the NSDF Project on Canada warbler in the Application Case is provided for each measurement indicator in Table 5.6.7-5. Residual effects were described after the implementation of effective mitigation, and summarized according to direction, magnitude, geographic extent, duration/reversibility, frequency/timing, and likelihood of the effect occurring following the methods described in Section 5.6.6.3 and the definitions provided in Table 5.6.6-1.

Table 5.6.7-5: Classification of Residual Effects on Canada Warbler in the Application Case

Indicator	Characteristic	Rating/Effect Size
Habitat Availability	Direction	Negative
	Magnitude	Direct loss of 25 ha of suitable habitat; reduced quality of nesting habitat and possible avoidance in the LSA from sensory disturbance during construction and operations
	Geographic Extent	Project Footprint (direct habitat loss); Local (sensory disturbance)
	Duration/Reversibility	Permanent (direct habitat loss)/Irreversible; Long-term (sensory disturbance)
	Frequency/Timing	Continuous
	Likelihood	Certain (direct habitat loss); Probable (sensory disturbance)
Habitat Distribution	Direction	Negative
	Magnitude	Small change in movement in the LSA, with individuals travelling along the perimeter of the LSA more frequently as a result of the NSDF Project
	Geographic Extent	Local
	Duration/Reversibility	Permanent/Irreversible
	Frequency/Timing	Continuous
	Likelihood	Probable
Survival and Reproduction	Direction	Negative
	Magnitude	Small reduction in carrying capacity from habitat loss and sensory disturbance
	Geographic Extent	Local
	Duration/Reversibility	Long-term (sensory disturbance)
	Frequency/Timing	Continuous
	Likelihood	Probable

5.6.7.2.4 Determination of Significance

The loss/degradation of overwintering habitat may be the most important factor affecting the Canada warbler population that overlaps the RSA at Base Case (Environment Canada 2016b). The loss/degradation of breeding habitat is also considered a primary threat, but its relative importance varies across the species' geographic range (Environment Canada 2016b). Other threats affecting this VC at Base Case include accidental mortality (e.g., collision with anthropogenic structures), and changes in the availability of insect prey (Environment Canada 2016b). Canada warblers may have a low ability to adapt to changes because they are a single-brooded species that arrives late on the breeding grounds and leaves early. However, Canada warblers also have the ability to produce many young, which increases the species' resilience to changes in survival and reproduction.

Ontario may support 50% of Canada's breeding population of this VC and 15.7% of the RSA is comprised of suitable habitat for this species. Habitat availability for the population of Canada warbler that overlaps with the RSA is not considered a limiting factor at Base Case and changes to this indicator have not exceeded its resilience or adaptability limits. Existing disturbance in the RSA and LSA do not likely function as dispersal barriers for this species in the Base Case because it is highly mobile.

The federal recovery strategy states that "there are currently adequate numbers of individuals to sustain the species in Canada or increase its abundance with the implementation of proper conservation actions" (Environment Canada 2016b). Therefore, changes to Canada warbler survival and reproduction in the Base Case are considered to be within the resilience and adaptability limits of this species.

For the primary pathways influencing habitat availability, habitat distribution and survival and reproduction, the residual effects of the NSDF Project are predicted to be negative in direction and restricted to the NSDF Project footprint or LSA in geographic extent, which implies that at least a portion of the population is affected during any given year, but likely not the entire population every year. In the Application Case, the NSDF Project footprint is predicted to remove 25 ha of suitable Canada warbler habitat in the RSA. In addition, there may be changes to Canada warbler movement in the LSA as Canada warblers may not be willing to cross the gap in the forest created by the NSDF Project footprint. Suitable habitat in the LSA may be avoided by Canada warbler due to sensory disturbance during construction and operations. Effects from habitat loss are expected to be permanent because the development of the NSDF Project will result in the permanent reconfiguration of habitat on the landscape. Conversely, effects from sensory disturbance during construction and operation of the NSDF Project are expected to be continuous and reversible at the end of operations (long-term); although some individuals may adapt to sensory disturbance over the medium-term.

Although these changes are negative, they are relatively small in a population context. After implementation of mitigation, the incremental changes due to the NSDF Project are not predicted to adversely affect populations of Canada warbler that overlap with the RSA. Consequently, effects on Canada warbler habitat availability, habitat distribution, and survival and reproduction in the Application Case are predicted to be not significant.

Ongoing fire suppression in the RSA may reduce Canada warbler habitat availability as fire creates natural forest gaps with complex and dense shrubby cover required by this species (Environment Canada 2016b). Climate change is also likely to affect the Canada warbler population for the foreseeable future, although the direction and magnitude of changes are uncertain because predictions are based on simulations that can be highly variable and many scenarios are possible. Warmer and drier conditions in Ontario due to climate change may alter the onset of spring and summer and the timing of insect hatches (Nituch and Bowman 2013).

Insectivorous long-distance migrants, such as Canada warblers, often exhibit a strong synchronization between breeding and peak food abundance, and climate change may impact this timing by creating a temporal mismatch between reproduction and optimal foraging conditions for prey (Both et al. 2009). A longer growing season may allow for Canada warblers to raise more than one clutch per year, which is currently not possible with the timing of this species migration patterns (COSEWIC 2008).

Climate change is also predicted to increase the frequency and intensity of extreme weather events, including droughts, forest fires, and heavy precipitation (Huff and Thomas 2014). Extreme weather events during the breeding season can result in reduced fecundity and nest success. Forest fires may increase habitat availability by creating nesting habitat through the creation of gaps in the forest that contain a dense shrub layer. Individuals may also be susceptible to extreme weather events outside of the breeding season. The frequency and intensity of hurricanes are predicted to increase as a result of climate change, which may negatively affect individuals during fall migration and on wintering grounds.

Overall, the weight of evidence from the analysis of the primary pathways predicts that changes to Canada warbler habitat availability, habitat distribution, and survival and reproduction in the RSA as a result of the NSDF Project are within the resilience and adaptability limits of the species. Continued fire suppression in the RSA and climate change are expected to also affect Canada warbler habitat availability, habitat distribution, and survival and reproduction in the RSA. However, neither of these threats has been identified as being of high concern to the persistence of the species (Environment Canada 2016b). Therefore, effects from continued fire suppression and climate change in conjunction with the effects of the NSDF Project and past and present activities and developments in the RSA are not predicted to exceed the resilience and adaptability limits of the Canada warbler population that overlaps with the RSA. Consequently, cumulative effects of previous and existing developments, the incremental effect of the NSDF Project, and consideration of future, beyond regional disturbance factors (e.g., climate change) on the Canada warbler population that overlaps with the RSA, are predicted to be not significant.

5.6.7.3 Eastern Whip-poor-will

5.6.7.3.1 Residual Effects Analysis

Habitat Availability

The NSDF Project is estimated to remove approximately 1 ha of suitable breeding habitat for eastern whip-poor-will (Table 5.6.7-6). Sensory disturbance during construction, operation and closure phases may indirectly reduce eastern whip-poor-will habitat availability in the LSA through avoidance. Noise levels greater than 50 dB can negatively affect birds (ECCC 2016a). Eastern whip-poor-will may avoid otherwise suitable habitat in areas where NSDF Project activities create noise levels greater than 50 dB.

Table 5.6.7-6: Changes to Eastern Whip-poor-will Breeding Habitat Availability in the Application Case

Habitat Suitability	Regional Study Area				Local Study Area			
	Base Case [ha]	Application Case [ha]	Change in Area [ha]	Percent Change [%]	Base Case [ha]	Application Case [ha]	Change in Area [ha]	Percent Change [%]
Suitable	769	768	-1	-0.3	9	8	-1	-14.3
Unsuitable	3,083	3,085	1	0.1	194	195	1	0.7

ha = hectare; % = percent.

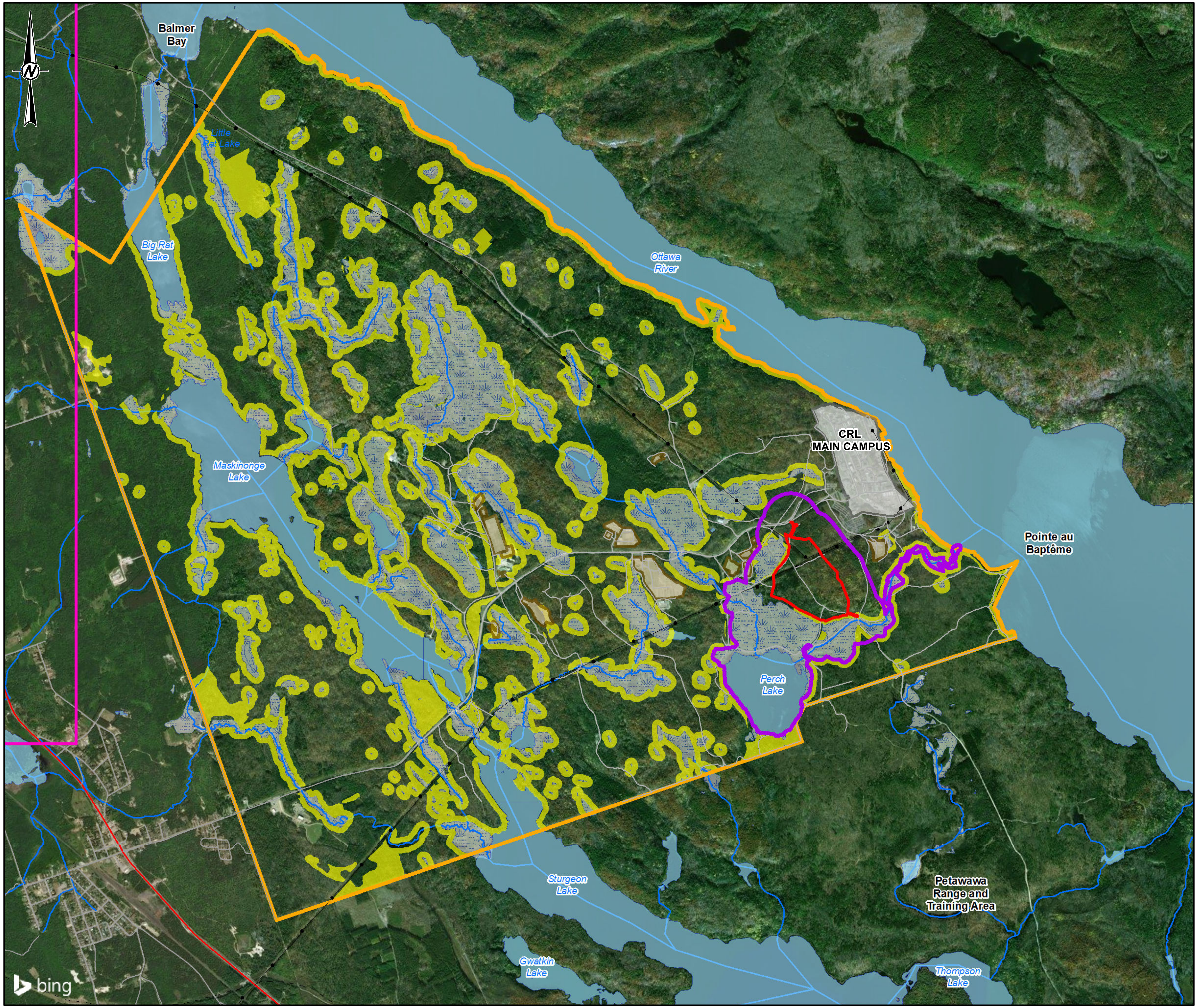
Effects on whip-poor-will from changes to habitat availability are expected because there is anticipated to be a direct loss of suitable breeding habitat; indirect habitat loss from avoidance due to sensory disturbance is also probable. Although effects are assumed to be cease after the completion of closure activities; some individuals may adapt to sensory disturbance and may use suitable habitat within one to three years after NSDF Project construction is complete.

Habitat Distribution

The development of the NSDF Project is unlikely to have a measurable effect on eastern whip-poor-will habitat distribution and movement in the RSA given the small size of the NSDF Project footprint and its location in the southeastern portion of the RSA, where most existing human disturbance is concentrated (Figure 5.6.7-5). Whip-poor-wills are highly mobile and capable of moving around or over the NSDF Project infrastructure. Forest clearing in the NSDF Project footprint is approximately 30 ha. Whip-poor-wills may perceive this area of forest clearing as a barrier to movement (Desrochers and Hannon 1997; St. Clair et al. 1998); however, the land around the NSDF Project footprint will remain in natural cover, which is primarily forest, allowing individuals to move around the NSDF Project during transit. The NSDF Project footprint represents a large portion of the LSA (14.8%) and is expected to affect whip-poor-will movement locally, with individuals travelling along the perimeter of the LSA more frequently in the Application Case than in the Base Case, as a result of the NSDF Project footprint being located in the centre of the LSA (Figure 5.6.7-6). However, the NSDF Project footprint is less likely to be perceived as a movement barrier by species that use earlier successional habitats, such as eastern whip-poor-wills than by interior-forest species.

This page left intentionally blank

232 509220 REPT 004
UNRESTRICTED



LEGEND

- HIGHWAY
- ROAD
- TRANSMISSION LINE
- NATURAL GAS PIPELINE
- RIVER/STREAM
- WATERBODY
- WETLAND
- CRL MAIN CAMPUS
- WASTE MANAGEMENT AREA (WMA)[1]
- REGIONAL STUDY AREA (CRL PROPERTY)
- LOCAL STUDY AREA
- SITE STUDY AREA (NSDF PROJECT SITE)
- EASTERN WHIP-POOR-WILL HABITAT
- 10 km^2 GRID SQUARE CONTAINING CRITICAL HABITAT

1 0 1
1:35,000 KILOMETRES

NOTE(S)
1. LIQUID DISPOSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.

REFERENCE(S)
1. BASEDATA MNRF 2016 AND CANVEC 2016
2. IMAGERY: © 2017 DIGITALGLOBE IMAGE COURTESY OF USGS EARTHSTAR GEOGRAPHICS SIO © 2017 MICROSOFT CORPORATION
3. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE18N

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
EASTERN WHIP-POOR-WILL HABITAT AVAILABILITY AND DISTRIBUTION IN THE RSA – APPLICATION CASE

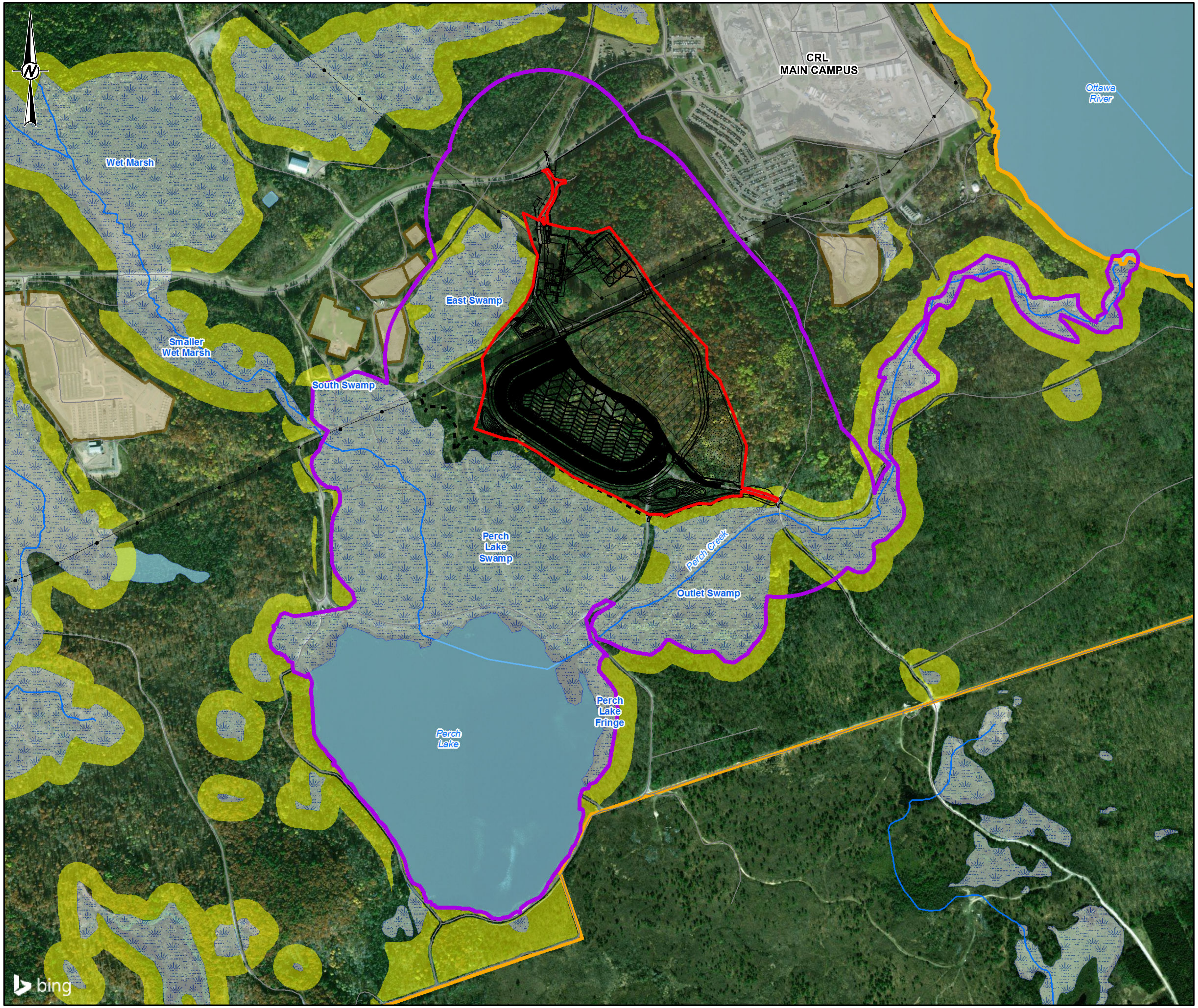
CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	BB
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.6.7-5

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm

This page left intentionally blank



LEGEND

- HIGHWAY
- ROAD
- TRANSMISSION LINE
- RIVER/STREAM
- WATERBODY
- WETLAND
- FENCE
- INFRASTRUCTURE
- LAYDOWN AREA
- STOCKPILE
- CRL MAIN CAMPUS
- WASTE MANAGEMENT AREA (WMA)[1]
- REGIONAL STUDY AREA (CRL PROPERTY)
- LOCAL STUDY AREA
- SITE STUDY AREA (NSDF PROJECT SITE)
- EASTERN WHIP-POOR-WILL HABITAT

250 0 250

1:10,000 METRES

NOTE(S)

1. LIQUID DISPOSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.

REFERENCE(S)

1. BASEDATA MNRF 2016 AND CANVEC 2016
2. IMAGERY: © 2010 DIGITALGLOBE IMAGE COURTESY OF USGS EARTHSTAR GEOGRAPHICS SIO © 2017 MICROSOFT CORPORATION
3. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE18N

CLIENT

CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT

NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE

EASTERN WHIP-POOR-WILL HABITAT AVAILABILITY AND DISTRIBUTION IN THE LSA AND SSA – APPLICATION CASE

CONSULTANT

Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	BB
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.6.7-6

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm

S:\Clients\Canadian_Nuclear_Laboratories\NSDF\99_PROJ\1547525_NSDF_EIS\40_PROD\0009_EIS_Section_5\Section_5_6_Terrestrial\1547525-0009-RT-0021.mxd

This page left intentionally blank

Survival and Reproduction

Site clearing for the NSDF Project is not predicted to cause whip-poor-will mortality. Adult whip-poor-wills are mobile and can avoid interactions with activities that could result in direct mortality, and mitigation will be implemented to avoid nest loss (Section 5.6.5.2.1). The loss of breeding habitat may affect reproductive success if individuals are displaced or return to breeding grounds to find habitat removed, and subsequently, are unable to establish a new territory or establish a territory in lower quality habitat. The loss of suitable breeding habitat due to the NSDF Project is predicted to result in a small reduction in the carrying capacity of the LSA and RSA. However, this is unlikely to have a measurable effect on the eastern whip-poor-will population in the RSA given the small area of predicted habitat loss (0.3% of suitable habitat in the RSA) and good representation of suitable habitat in the RSA (20.0% of RSA). Sensory disturbance may affect reproductive success and survival in the LSA by raising stress levels and interfering with communications (e.g., reducing ability to hear approaching predators or intraspecific vocalizations) (Ortega 2012). Thus, the carrying capacity of the LSA and RSA may be reduced in the Application Case relative to conditions at Base Case.

5.6.7.3.2 Prediction Confidence

The residual effects assessment for eastern whip-poor-will is based on a good understanding of whip-poor-will ecology and the species' tolerance to anthropogenic activities, and a moderate understanding of threats to the persistence of the species.

There is moderate uncertainty concerning the whip-poor-will population in the RSA because few quantitative data are available. There is moderate confidence in the habitat mapping. Some uncertainty exists in the accuracy of the mapping layer used to predict habitat availability, which was defined by relatively coarse vegetation community categories that did not always capture detailed habitat preferences. Also, the age of forested stands in the RSA may be underestimated; although information on stand age was available in the FRI data, the dates associated with polygon delineation were not provided with the dataset, and therefore, stand age could not be corrected based on the age of the dataset. Finally, the mapping could not be validated due to the limited amount of ground-truthing data available. This assessment dealt with uncertainty in map accuracy by making precautionary assumptions about habitat availability and occupancy in the study areas and most likely overestimating the amount of habitat loss and reduction in carrying capacity.

There is a high level of uncertainty associated with the future population status of whip-poor-will in Canada. Evidence suggests that populations are declining across the species' range, including in Ontario. If the declining population trend is not reversed or accelerates over the next decade, then whip-poor-will may be up-listed from threatened to endangered. The federal recovery strategy has partially identified critical habitat for the species and outlines a schedule to further identify critical habitat by 2035; and one or more action plans will be developed for this species by 2020 (Environment Canada 2015a).

5.6.7.3.3 Residual Effects Classification

A summary of the classification of incremental adverse residual effects of the NSDF Project on eastern whip-poor-will in the Application Case is provided for each measurement indicator in Table 5.6.7-7. Residual effects were described after the implementation of effective mitigation, and summarized according to direction, magnitude, geographic extent, duration/reversibility, frequency/timing, and likelihood of the effect occurring following the methods described in Section 5.6.6.3 and the definitions provided in Table 5.6.6-1.

Table 5.6.7-7: Description of Residual Effects on Eastern Whip-poor-will in the Application Case

Indicator	Characteristic	Rating/Effect Size
Habitat Availability	Direction	Negative
	Magnitude	Loss of 1 ha of suitable habitat (14.3% in LSA; 0.3% in RSA)
	Geographic Extent	Project Footprint (direct habitat loss); Local (sensory disturbance)
	Duration/Reversibility	Permanent
	Frequency/Timing	Continuous
	Likelihood	Certain
Habitat Distribution	Direction	Negative
	Magnitude	Small change in movement in the LSA, with individuals travelling along the perimeter of the LSA more frequently as a result of the NSDF Project
	Geographic Extent	Project Footprint (direct habitat loss); Local (sensory disturbance)
	Duration/Reversibility	Permanent
	Frequency/Timing	Continuous
	Likelihood	Probable
Survival and Reproduction	Direction	Negative
	Magnitude	Small reduction in reproductivity from habitat loss and sensory disturbance
	Geographic Extent	Local
	Duration/Reversibility	Permanent
	Frequency/Timing	Continuous
	Likelihood	Probable

5.6.7.3.4 Determination of Significance

The population of eastern whip-poor-will that overlaps with the RSA is not considered sensitive to changes in habitat availability or distribution because breeding habitat is not considered a limiting factor for this criterion in the RSA, and suitable habitat is well represented (20.0% of RSA) and well distributed in the RSA. The RSA overlaps one 10 km by 10 km standardized UTM grid square identified to contain critical habitat for this species (grid square 18US00; Environment Canada 2015a). However, the area of overlap is small (28 ha) and is located in the extreme northwestern tip of the RSA (Figure 5.6.7-5). The exact location of critical habitat in grid squares is not identified in recovery strategies. Based on habitat mapping, approximately 3 ha of suitable habitat occurs in the grid square where it overlaps with the RSA. Whip-poor-wills are highly mobile and they demonstrate flexibility in habitat selection, including use of human disturbance, such as clear cuts and utility corridors. These characteristics suggest resilience and adaptability to changes in habitat availability and distribution. Whip-poor-wills have been regularly reported using habitats in areas surrounding the RSA (eBird 2016), and seven individuals were observed in and around the RSA during species-specific surveys. Despite concerning population trend data, the federal recovery strategy concluded that individuals that are capable of reproduction are available to sustain the population and improve its abundance (Environment Canada 2015a). Therefore, changes to whip-poor-will survival and reproduction in the Base Case are considered to be within the resilience and adaptability limits of this species. Overall, there is no evidence to suggest the population that overlaps the RSA is not self-sustaining and ecologically effective at Base Case.

In the Application Case, the NSDF Project footprint would permanently remove approximately 1 ha of suitable breeding habitat during construction. Additional suitable breeding habitat in the LSA may be avoided due to sensory disturbance. The NSDF Project would result in a change in movement patterns at the local scale, but this change is not expected to alter the extent of occurrence of the population that overlaps with the RSA because the area of disturbance is small and localized, and whip-poor-wills are highly mobile and capable of using anthropogenic disturbances for breeding. With effective implementation of mitigation, the incremental changes due to the NSDF Project are not predicted to adversely affect the population of whip-poor-wills that overlaps with the RSA because habitat is unlikely to be a limiting factor in the RSA and direct mortality of individuals will be avoided by implementing appropriate mitigation. Therefore, effects from the NSDF Project are not predicted to exceed the resilience and adaptability limits of the whip-poor-will population that overlaps with the RSA. Consequently, cumulative effects from the NSDF Project and previous and existing activities and developments in the RSA on the eastern whip-poor-will population that overlaps with the RSA are predicted to be not significant in the Application Case.

Ongoing fire suppression in the RSA may reduce whip-poor-will habitat availability as forests progress towards old growth age and lose preferred attributed of nesting and foraging habitat (Environment Canada 2015a). Climate change is also likely to affect the whip-poor-will population for the foreseeable future, although the direction and magnitude of changes are uncertain because predictions are based on simulations that can be highly variable and many scenarios are possible. Warmer and drier conditions in Ontario due to climate change may alter the onset of spring and summer and the timing of insect hatches (Nituch and Bowman 2013). Insectivorous, long-distance migrants such as eastern whip-poor-wills often exhibit a strong synchronization between breeding and peak food abundance, and climate change may impact this timing by creating a temporal mismatch between reproduction and optimal foraging conditions for prey (Both et al. 2009; COSEWIC 2009). On the contrary, an anticipated longer growing season may have a positive effect on eastern whip-poor-will by allowing for this species to increasingly raise more than one clutch per year. However, climate change is also predicted to increase the frequency and intensity of extreme weather events, including droughts, forest fires, and heavy precipitation (Environment Canada 2015a; Huff and Thomas 2014). Extreme weather events during the breeding season can result in reduced fecundity and nest success. Forest fires may increase habitat availability by creating foraging habitat and eventually nesting habitat through succession. Individuals may also be susceptible to extreme weather events outside of the breeding season. The frequency and intensity of hurricanes are predicted to increase as a result of climate change, which may negatively affect individuals during fall migration and on wintering grounds.

Overall, the weight of evidence from the analysis of the primary pathways predicts that changes to eastern whip-poor-will habitat availability, habitat distribution, and survival and reproduction in the RSA as a result of the NSDF Project are within the resilience and adaptability limits of the species. Continued fire suppression in the RSA and climate change are expected to also affect whip-poor-will habitat availability, habitat distribution, and survival and reproduction in the RSA. However, neither of these threats has been identified as being of high concern to the persistence of the species (Environment Canada 2015a). Therefore, effects from continued fire suppression and climate change in conjunction with the effects of the NSDF Project and past and present activities and developments in the RSA are not predicted to exceed the resilience and adaptability limits of the whip-poor-will population that overlaps with the RSA. Consequently, cumulative effects of previous and existing developments, the incremental effect of the NSDF Project, and consideration of future, beyond regional disturbance factors (e.g., climate change) on the eastern whip-poor-will population that overlaps the RSA are predicted to be not significant.

5.6.7.4 Golden-winged Warbler

5.6.7.4.1 Residual Effects Analysis

Habitat Availability

The NSDF Project is estimated to remove 24 ha of suitable breeding habitat for golden-winged warbler, which is 25.4% of suitable habitat in the LSA and 0.9% of suitable habitat in the RSA (Table 5.6.7-8). Sensory disturbance during construction, operation and closure phases may reduce golden-winged warbler habitat availability in the LSA through avoidance. Noise levels greater than 50 dB can negatively affect birds (ECCC 2016a). Golden-winged warbler may avoid otherwise suitable habitat in areas where NSDF Project activities create noise levels greater than 50 dB.

Table 5.6.7-8: Changes to Golden-winged Warbler Breeding Habitat Availability in the Application Case

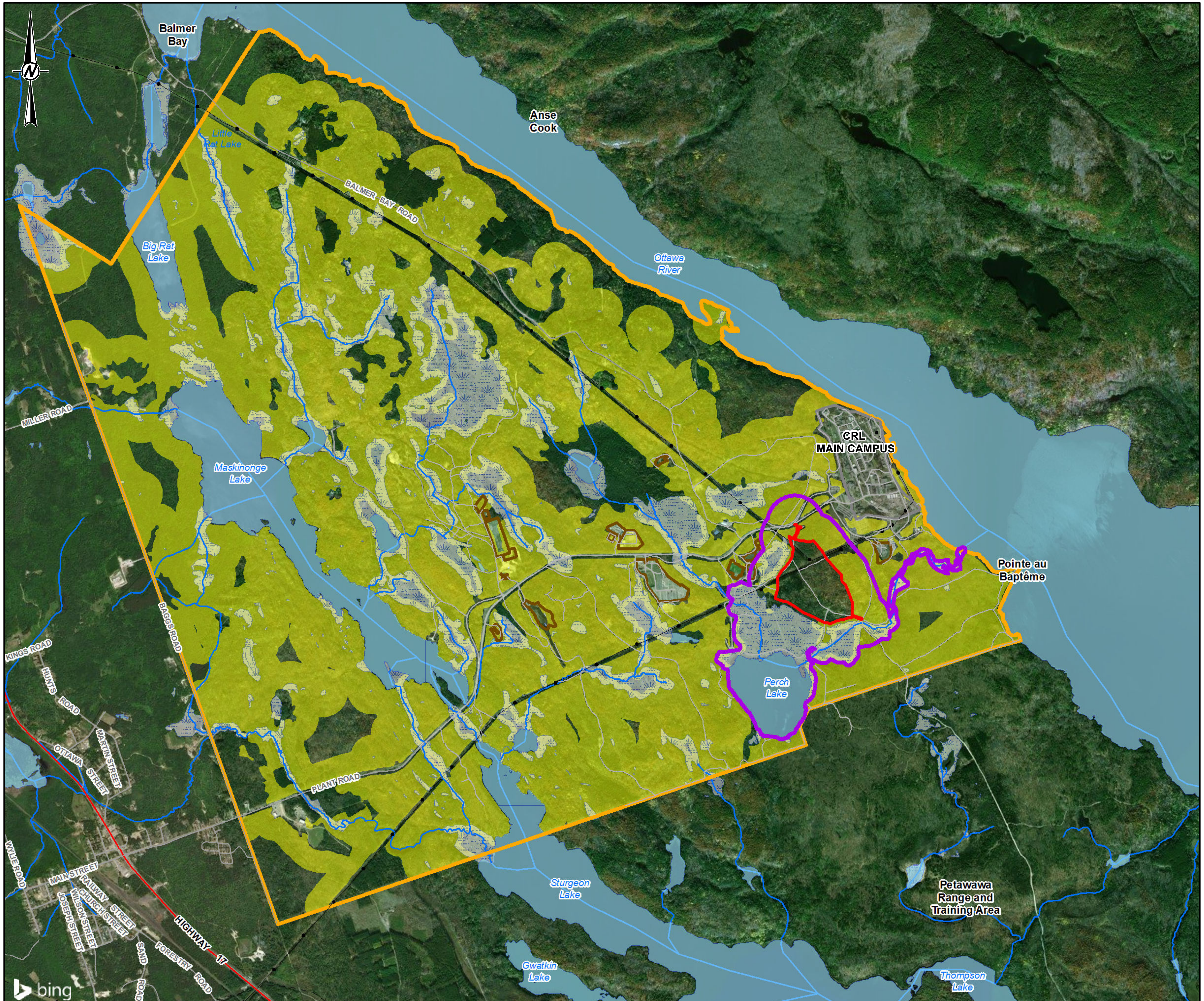
Habitat Suitability	Regional Study Area				Local Study Area			
	Base Case [ha]	Application Case [ha]	Change in Area [ha]	Percent Change [%]	Base Case [ha]	Application Case [ha]	Change in Area [ha]	Percent Change [%]
Suitable	2,621	2,597	-24	-0.9	94	70	-24	-25.4
Unsuitable	1,232	1,255	24	1.9	109	133	24	21.8

ha = hectare; % = percent.

Effects on golden-winged warbler from changes to habitat availability are expected because there will be a direct loss of suitable breeding habitat and indirect habitat loss from avoidance due to sensory disturbance is also probable. Effects from sensory disturbance are conservatively assumed to cease after completion of closure activities; however, some individuals may adapt to sensory disturbance and may use suitable habitat within one to three years after construction is complete.

Habitat Distribution

The development of the NSDF Project is unlikely to have a measurable effect on golden-winged warbler habitat distribution and movement in the RSA given the small size of the NSDF Project footprint, and its location in the southeastern portion of the RSA, where most existing human disturbance is concentrated (Figure 5.6.7-7). Golden-winged warblers are highly mobile and capable of moving around or over the NSDF Project infrastructure. Forest clearing in the NSDF Project footprint is approximately 30 ha. Golden-winged warblers may perceive this area of forest clearing as a barrier to movement (Desrochers and Hannon 1997); however, the land around the NSDF Project footprint will remain in natural cover, which is primarily forest, allowing individuals to move around the NSDF Project during transit (Figure 5.6.7-8). The NSDF Project footprint represents a large portion of the LSA (14.8%) and may affect golden-winged warbler movement, with individuals travelling along the perimeter of the LSA more frequently in the Application Case than in the Base Case as a result of the NSDF Project footprint being located in the centre of the LSA. However, the NSDF Project footprint is less likely to be perceived as a movement barrier by edge species, such as golden-winged warblers than by interior-forest species.



LEGEND
- HIGHWAY
- ROAD
- TRANSMISSION LINE
- NATURAL GAS PIPELINE
- RIVER/STREAM
- WATERBODY
- WETLAND
- CRL MAIN CAMPUS
- WASTE MANAGEMENT AREA (WMA)[1]
- REGIONAL STUDY AREA (CRL PROPERTY)
- LOCAL STUDY AREA
- SITE STUDY AREA (NSDF PROJECT SITE)
- GOLDEN-WINGED WARBLER HABITAT

1 0 1
1:35,000 KILOMETRES

NOTE(S)
1. LIQUID DISPOSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.

REFERENCE(S)
1. BASEDATA MNRF 2016 AND CANVEC 2016
2. IMAGERY: © 2010 DIGITALGLOBE IMAGE COURTESY OF USGS EARTHSTAR GEOGRAPHICS SIO © 2017 MICROSOFT CORPORATION
3. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE18N

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
GOLDEN-WINGED WARBLER HABITAT AVAILABILITY AND DISTRIBUTION IN THE RSA – APPLICATION CASE

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	KS
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.6.7-7

This page left intentionally blank

LEGEND

- HIGHWAY
- ROAD
- TRANSMISSION LINE
- RIVER/STREAM
- WATERBODY
- WETLAND
- FENCE
- INFRASTRUCTURE
- LAYDOWN AREA
- STOCKPILE
- CRL MAIN CAMPUS
- WASTE MANAGEMENT AREA (WMA)[1]
- REGIONAL STUDY AREA (CRL PROPERTY)
- LOCAL STUDY AREA
- SITE STUDY AREA (NSDF PROJECT SITE)
- GOLDEN-WINGED WARBLER HABITAT

250 0 250

1:10,000 METRES

NOTE(S)

1. LIQUID DISPOSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.

REFERENCE(S)

1. BASEDATA MNRF 2016 AND CANVEC 2016
2. IMAGERY: © 2017 DIGITALGLOBE IMAGE COURTESY OF USGS EARTHSTAR GEOGRAPHICS SIO © 2017 MICROSOFT CORPORATION
3. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE18N

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
GOLDEN-WINGED WARBLER HABITAT AVAILABILITY AND DISTRIBUTION IN THE LSA AND SSA – APPLICATION CASE

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	KS
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	**5.6.7-8**

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm 0

This page left intentionally blank

Survival and Reproduction

Site clearing for the NSDF Project is not predicted to cause golden-winged warbler mortality. Adult golden-winged warblers are mobile and can avoid interactions with activities that could result in direct mortality, and mitigation will be implemented to avoid nest loss (Section 5.6.5.2.1). The loss of breeding habitat may affect reproductive success if individuals are displaced or return to breeding grounds to find habitat removed, and subsequently, are unable to establish a new territory or establish a territory in lower quality habitat. The loss of suitable breeding habitat due to the NSDF Project is predicted to result in a small reduction in the carrying capacity of the LSA and RSA. However, this is unlikely to have a measurable effect on the golden-winged warbler population in the RSA given the small area of predicted habitat loss (0.9% of suitable habitat in the RSA) and overall abundance of suitable habitat in the RSA (68.0% of RSA).

Sensory disturbance, such as noise from construction of the NSDF Project may affect reproductive success and survival in the LSA by raising stress levels and interfering with communications (e.g., reducing ability to hear approaching predators or intraspecific vocalizations) (Ortega 2012). Thus, the carrying capacity of the LSA and RSA may be further reduced relative to that predicted based on habitat loss alone.

5.6.7.4.2 Prediction Confidence

The residual effects assessment for golden-winged warbler is based on a good understanding of golden-winged warbler ecology, threats to the persistence of the species and the species' tolerance to anthropogenic activities. There is moderate uncertainty concerning the golden-winged warbler population in the RSA because few quantitative data are available. Some uncertainty exists in the accuracy of the mapping layer used to predict habitat availability, which was defined by relatively coarse vegetation community categories that did not always capture detailed habitat preferences. Also, the age of forested stands in the RSA may be underestimated; although information on stand age was available in the FRI data, the dates associated with polygon delineation were not provided with the dataset, and therefore, stand age could not be corrected based on the age of the dataset. Finally, the mapping could not be validated due to the limited amount of ground-truthing data available. This assessment dealt with uncertainty in map accuracy by making precautionary assumptions about habitat availability and occupancy in the study areas and most likely overestimating the amount of habitat loss and reduction in carrying capacity.

There is a moderate level of uncertainty associated with the future population status of golden-winged warbler in Canada. There are discrepancies among population trend estimate, with some suggesting steep declines across the species' range, and others suggesting stable population trends (ECCC 2016c). The federal recovery strategy has partially identified critical habitat for the species and outlines a schedule to further identify critical habitat by 2023; and one or more action plans will be developed for this species by 2022 (ECCC 2016c).

5.6.7.4.3 Residual Effects Classification

A summary of the classification of incremental adverse residual effects of the NSDF Project on golden-winged warbler in the Application Case is provided for each measurement indicator in Table 5.6.7-9. Residual effects were described after the implementation of effective mitigation, and summarized according to direction, magnitude, geographic extent, duration/reversibility, frequency/timing, and likelihood of the effect occurring following the methods described in Section 5.6.6.3 and the definitions provided in Table 5.6.6-1.

Table 5.6.7-9: Description of Residual Effects on Golden-winged Warbler in the Application Case

Indicator	Characteristic	Rating/Effect Size
Habitat Availability	Direction	Negative
	Magnitude	Loss of 24 ha of suitable habitat (25.4% in LSA; 0.9% in RSA)
	Geographic Extent	Project Footprint (direct habitat loss); Local (sensory disturbance)
	Duration/Reversibility	Permanent (direct habitat loss)/Irreversible; Long-term (sensory disturbance)
	Frequency/Timing	Continuous
	Likelihood	Certain (direct habitat loss); Probable (sensory disturbance)
Habitat Distribution	Direction	Negative
	Magnitude	Small change in movement in the LSA, with individuals travelling along the perimeter of the LSA more frequently as a result of the NSDF Project
	Geographic Extent	Local
	Duration/Reversibility	Permanent/Irreversible
	Frequency/Timing	Continuous
	Likelihood	Probable
Survival and Reproduction	Direction	Negative
	Magnitude	Small reduction in reproductivity from habitat loss and sensory disturbance
	Geographic Extent	Local
	Duration/Reversibility	Permanent/Irreversible
	Frequency/Timing	Continuous
	Likelihood	Probable

5.6.7.4.4 Determination of Significance

The population of golden-winged warbler that overlaps with the RSA is not considered sensitive to changes in habitat availability or distribution because breeding habitat is not considered a limiting factor for this criterion in the RSA, and suitable habitat is abundant (68.0% of RSA) and well distributed in the RSA. The RSA falls within one of the focal areas (GL10) identified to contain core populations that sustain the current breeding distribution and are important for expanding the population into adjacent areas; however, the RSA does not overlap grid squares identified to contain critical habitat within the focal area (ECCC 2016c). Golden-winged warblers are highly mobile and they demonstrate flexibility in habitat selection, including use of human disturbance such as roadsides and utility corridors, which create edge habitat preferred by this species. These characteristics suggest resilience and adaptability to changes in habitat availability and distribution. The population objective for golden-winged warbler, as identified in the federal recovery strategy, is to maintain self-sustaining populations in the focal areas, which indicates the population overlapping the RSA is considered to be relatively stable. Therefore, changes to golden-winged warbler survival and reproduction in the Base Case are considered to be within the resilience and adaptability limits of this species. Overall, there is no evidence to suggest the population that overlaps the RSA is not self-sustaining and ecologically effective at Base Case.

In the Application Case, the NSDF Project footprint would permanently remove 24 ha of suitable breeding habitat during construction. Additional suitable breeding habitat in the LSA may be avoided due to sensory disturbance. The NSDF Project may result in a change in movement patterns at the local scale, but this change is not expected to alter the extent of occurrence of the population that overlaps with the RSA because the area of disturbance is

small and localized, and golden-winged warblers are highly mobile and capable of using anthropogenic disturbances for breeding. With effective implementation of mitigation, the incremental changes due to the NSDF Project are not predicted to adversely affect the population of golden-winged warblers that overlaps with the RSA because habitat is unlikely to be a limiting factor in the RSA and direct mortality of individuals will be avoided by implementing appropriate mitigation. Therefore, effects from the NSDF Project are not predicted to exceed the resilience and adaptability limits of the golden-winged warbler population that overlaps with the RSA. Consequently, cumulative effects from the NSDF Project and previous and existing activities and developments in the RSA on the golden-winged warbler population that overlaps with the RSA are predicted to be not significant in the Application Case.

Ongoing fire suppression in the RSA may reduce golden-winged warbler habitat availability as forests progress towards old growth age and habitat edge attributes preferred by this species are lost. Climate change is also likely to affect the whip-poor-will population for the foreseeable future, although the direction and magnitude of changes are uncertain because predictions are based on simulations that can be highly variable and many scenarios are possible. An anticipated longer growing season may have a positive effect on golden-winged warbler by allowing for this species to raise more than one clutch per year. However, climate change is also predicted to increase the frequency and intensity of extreme weather events, including droughts, forest fires, and heavy precipitation (Environment Canada 2015a; Huff and Thomas 2014). Extreme weather events during the breeding season can result in reduced fecundity and nest success. Forest fires may increase habitat availability by creating habitat edges preferred by this species. Individuals may also be susceptible to extreme weather events outside of the breeding season. The frequency and intensity of hurricanes are predicted to increase as a result of climate change, which may negatively affect individuals during fall migration and on wintering grounds.

Blue-winged warblers continue to expand northward and this may be exacerbated by climate change and fire suppression (ECCC 2016c). Although both warbler species are considered early- to mid-successional habitat specialists, blue-winged warblers will start nesting at a later stage of succession and continue to nest further into succession than golden-winged warblers (Gill et al. 2001). An expansion of the blue-winged warbler range into the RSA would increase the likelihood of hybridization and competition with the golden-winged warbler population overlapping with the RSA (ECCC 2016c). However, further research is required to determine the taxonomic relationship between these species given that recent research suggests they are one species (Toews et al. 2016).

Overall, the weight of evidence from the analysis of the primary pathways predicts that changes to golden-winged warbler habitat availability, habitat distribution, and survival and reproduction in the RSA as a result of the NSDF Project are within the resilience and adaptability limits of the species. Continued fire suppression in the RSA, climate change, and potential northward range expansion of the blue-winged warbler into the RSA are expected to also affect golden-winged warbler habitat availability, habitat distribution, and survival and reproduction in the RSA. However, only hybridization with blue-winged warbler has been identified as being of high concern to the persistence of the species among these threats (ECCC 2016c), and it is uncertain if this is a threat. Therefore, effects from continued fire suppression, climate change, and potential northward range expansion of the blue-winged warbler into the RSA in conjunction with the effects of the NSDF Project and past and present activities and developments in the RSA are not predicted to exceed the resilience and adaptability limits of the golden-winged warbler population that overlaps with the RSA. Consequently, cumulative effects of previous and existing developments, the incremental effect of the NSDF Project, and consideration of future, beyond regional disturbance factors (e.g., climate change) on the golden-winged warbler population that overlaps the RSA are predicted to be not significant.

5.6.7.5 Bats

5.6.7.5.1 Residual Effects Analysis

Habitat Availability

The RSA contains extensive spatial coverage of potential maternity roost habitat (Table 5.6.7-10). The reduction in habitat availability caused by the NSDF Project at the RSA scale is relatively minor (i.e., 2%). At the LSA scale, there will be a larger relative decrease in the availability of potential maternity roost habitat (reduction in 31%). Site clearing and sensory disturbance during construction and operation of the NSDF Project could also result in adverse changes to the availability of potential bat maternity roosting habitat in the LSA adjacent to the NSDF Project footprint if the level of disturbance causes avoidance and abandonment of occupied maternity roosts. Detailed information on how bats respond to anthropogenic noise is limited, and varies among species; however, it is known that female bats may abandon their maternity roosts and young if noise is at a sufficient level. Bats have been found to abandon roosts when they are directly disturbed by human activity, especially those causing loud and sudden noises (California Department of Transportation 2016). Potential maternity roosting habitat is predicted to be affected in the immediate perimeter of the mature tree stands surrounding the SSA.

Maternity roosts are only seasonally occupied. Because vegetation clearing for the NSDF Project will be conducted outside of the bat maternity roosting period (May 1 to August 31) when potential roost trees are not occupied, the NSDF Project will not result in a loss of actively used habitat; however, some roosting habitat adjacent to the NSDF Project footprint could be adversely affected (i.e., through sensory disturbance) while it is occupied. All three species of bat exhibit high site fidelity to their maternity roosting sites, and therefore, the loss of high quality maternity roosting habitat, even while unoccupied, has the potential to displace some roosting bats that return to the area the summer after disturbance has occurred, and their former roost tree(s) have been removed.

Female bats displaced from the SSA are likely to find alternate maternity roosting habitat in adjacent stands of mature forest within the LSA or RSA. The availability of additional maternity rooting habitat for displaced bats is because maternity roosts are not likely a limiting factor within the RSA. Instead, bat populations overlapping with the RSA are limited by WNS and occur at densities that are likely to be well below the carrying capacity of the available habitat.

Sensory disturbance during construction and operation is assumed to degrade the quality of potential roosting habitat for bats in the LSA; however, the degree to which habitat would be avoided by bats is unknown and the effect is considered to be probable to occur. The effect would be highest during construction, with some low-level disturbance occurring through operations.

Table 5.6.7-10: Changes to Availability of Potential Bat Maternity Roost Tree Habitat in the Application Case

Habitat Suitability	Regional Study Area				Local Study Area			
	Base Case [ha]	Application Case [ha]	Change in Area [ha]	Percent Change [%]	Base Case [ha]	Application Case [ha]	Change in Area [ha]	Percent Change [%]
Suitable	1,149	1,124	-25	-2	80	55	-25	-31
Unsuitable	2,704	2,729	26	1	123	148	26	21

ha = hectare; % = percent.

The federal recovery strategy for the three bat species considered here describes the threat of roost destruction in WNS-affected areas as having a high level of concern and causal certainty (meaning there is strong evidence to link the threat to stresses on population viability; Environment Canada 2015b). Offsetting for removal of potential (but unverified) bat maternity roost trees (i.e., "residences") is not required under SARA, because potential roost trees will be removed during a period when they would be unoccupied. This is in keeping with the information provided to federal land managers regarding the emergency listing order for little brown bats, northern myotis and tri-colored bat (Environment Canada 2015c). This guidance document states:

> *Trees with active maternity roosts located on federal lands would be considered residences for bats under* SARA*. Bats generally use the same trees in the same forests and at the same time of the year as migratory birds. Federal land managers who already are aware of the prohibitions of the* Migratory Birds Convention Act, 1994*, and its regulations, would most likely be in compliance with the* SARA *prohibitions regarding destruction of a bat residence*.

The guidance clarifies that "active" maternity roosts are considered residences for bats under SARA.

Habitat Distribution

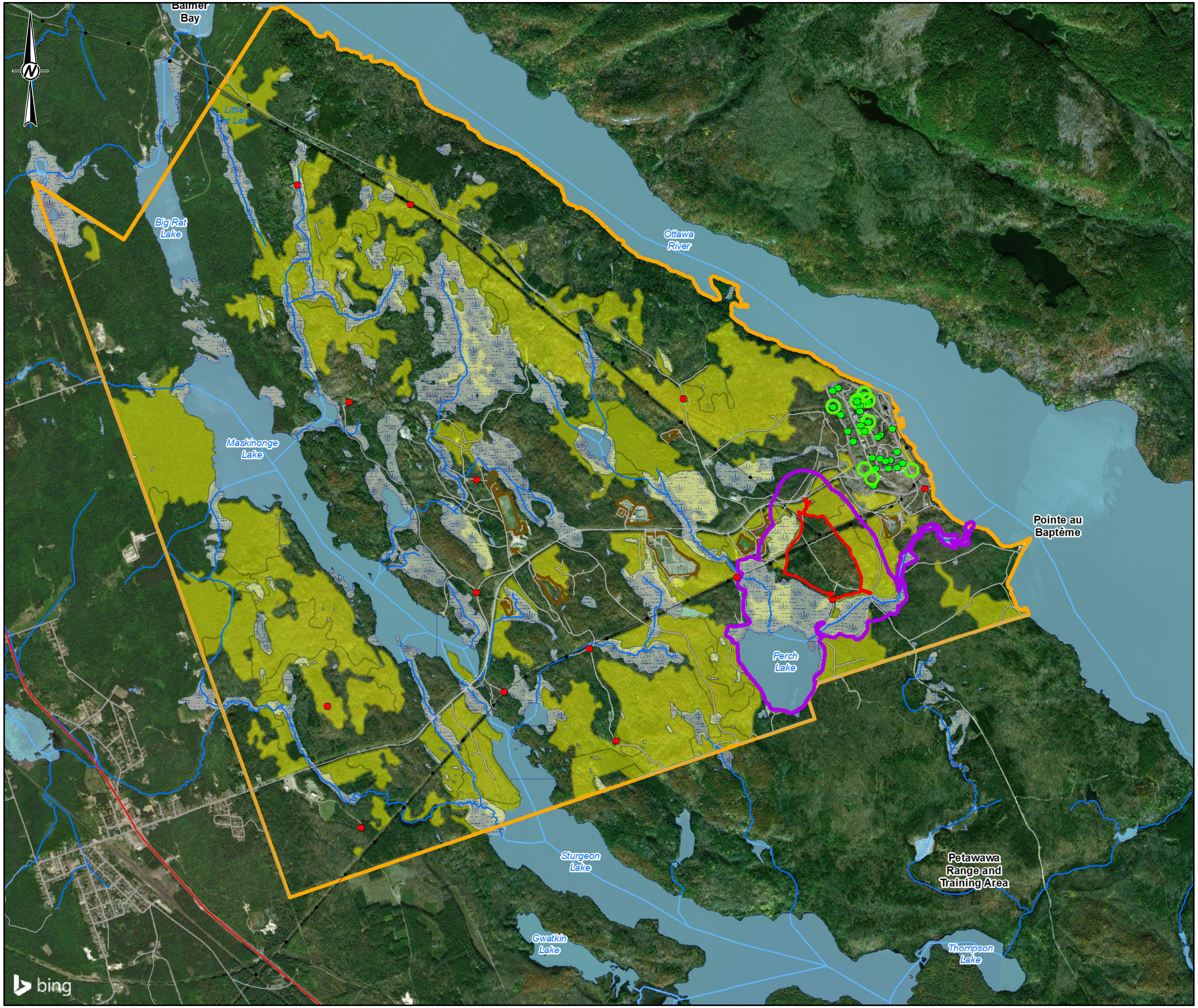
On the regional landscape, the NSDF Project footprint will result in the creation of a minor gap in otherwise relatively contiguous area of potential roosting habitat (Figure 5.6.7-9). The SSA contained linear gaps in the otherwise contiguous area of potential roosting habitat caused by East Mattawa Road and the two hydroelectric corridors in the Base Case. At the local scale, the NSDF Project will result in a relatively larger gap in the local distribution of potential maternity roost habitat in the Application Case, compared to the regional distribution (Figure 5.6.7-10).

The distribution of potential maternity roost habitat is also related to gaps and corridors between forested areas that are used for commuting and foraging. Little brown myotis, northern myotis and tri-colored bat commute between their forest roost habitat and forage areas and use watercourses (i.e., streams), forest edges, or travel above the forest canopy. They may use newly created edges of the SSA, which would improve their ability to disperse or search for food and water in the Application Case. There is uncertainty with this prediction because not all species use edge habitats in the same way, and they have differences in their tolerance for gap size in forest canopy coverage.

Although a positive change in movement patterns at a local scale is possible during operation, the overall net effect of the NSDF Project on habitat distribution is negative because there will be a loss of potential maternity roosting habitat for little brown myotis, northern myotis and tri-colored bat and a gap in potential maternity roosting habitat distribution, with the highest relative effects at the local scale. At a broader, national level, the NSDF Project is not expected to reduce the extent of occurrence of these three species, and is therefore compliant with the long-term distribution objective outlined in the recovery strategy, which is to restore the distribution of these populations to their known, pre-WNS extents of occurrence in Canada (Environment Canada 2015c).

This page intentionally left blank

232 509220 REPT 004
UNRESTRICTED



LEGEND

- HIGHWAY
- ROAD
- TRANSMISSION LINE
- NATURAL GAS PIPELINE
- RIVER/STREAM
- WATERBODY
- WETLAND
- CRL MAIN CAMPUS
- WASTE MANAGEMENT AREA (WMA)[1]
- REGIONAL STUDY AREA (CRL PROPERTY)
- LOCAL STUDY AREA
- SITE STUDY AREA (NSDF PROJECT SITE)
- POTENTIAL BAT MATERNITY ROOSTING HABITAT[2]

CNL STAFF BAT MONITORING LOCATIONS

- 2016 NO SARA-LISTED SPECIES RECORDED
- 2016 - AT LEAST 1 OF 3 SARA-LISTED SPECIES RECORD
- 2015 NO SARA-LISTED SPECIES RECORDED [2]
- 2015 - AT LEAST 1 OF 3 SARA-LISTED SPECIES RECORD

NOTE(S)

1. LIQUID DISPOSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.
2. POTENTIAL BAT MATERNITY ROOSTING HABITAT IS BASED ON HABITAT CONDITIONS, MATERNITY ROOST PRESENCE AND BAT OCCUPANCY HAS NOT YET BEEN VERIFIED.

REFERENCE(S)

1. BASEDATA MNRF 2016 AND CANVEC 2016
2. IMAGERY: © 2017 DIGITALGLOBE IMAGE COURTESY OF USGS EARTHSTAR GEOGRAPHICS SIO © 2017 MICROSOFT CORPORATION
3. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE18N

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
BAT HABITAT AVAILABILITY AND DISTRIBUTION IN THE RSA – APPLICATION CASE

CONSULTANT
Golder Associates

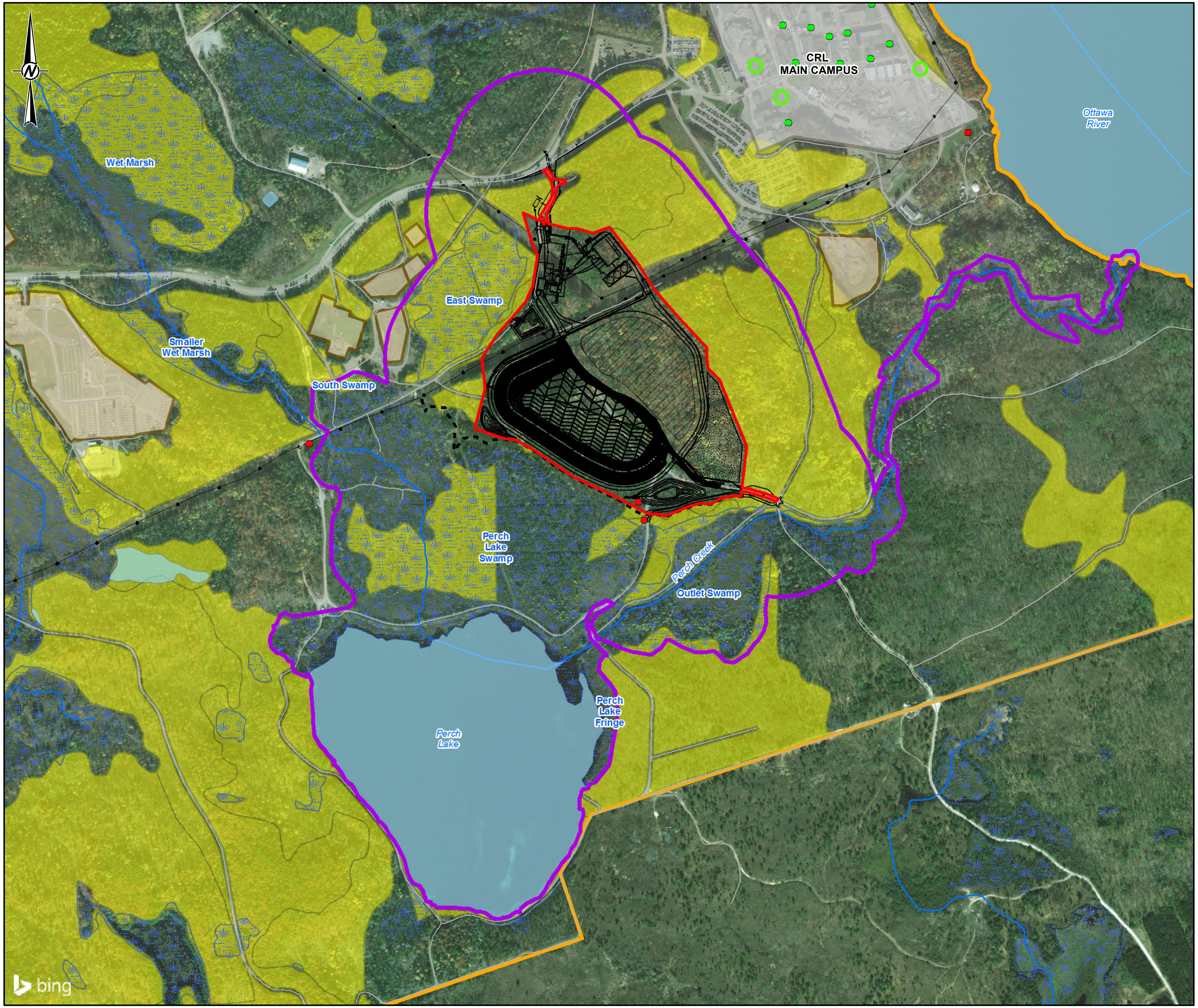
YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	KS
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.6.7-9

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:
25mm

S:\Clients\Canadian_Nuclear_Laboratories\NSDF\99_PROJ\1547525_NSDF_EIS\40_PROD\0009_EIS_Section_5\Section_5.6_Terrestrial\1547525-0009-RT-0024.mxd

This page left intentionally blank



LEGEND

- HIGHWAY
- ROAD
- TRANSMISSION LINE
- RIVER/STREAM
- WATERBODY
- WETLAND
- FENCE
- INFRASTRUCTURE
- LAYDOWN AREA
- STOCKPILE
- CRL MAIN CAMPUS
- WASTE MANAGEMENT SITES (WMA)[1]
- REGIONAL STUDY AREA (CRL PROPERTY)
- LOCAL STUDY AREA
- SITE STUDY AREA (NSDF PROJECT SITE)
- POTENTIAL BAT MATERNITY ROOSTING HABITAT[2]

CNL STAFF BAT MONITORING LOCATIONS

- 2016 NO SARA-LISTED SPECIES RECORDED
- 2016 - AT LEAST 1 OF 3 SARA-LISTED SPECIES RECORD
- 2015 NO SARA-LISTED SPECIES RECORDED [2]
- 2015 - AT LEAST 1 OF 3 SARA-LISTED SPECIES RECORD

250 0 250

1:10,000 METRES

NOTE(S)

1. LIQUID DISPOSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.
2. POTENTIAL BAT MATERNITY ROOSTING HABITAT IS BASED ON HABITAT CONDITIONS, MATERNITY ROOST PRESENCE AND BAT OCCUPANCY HAS NOT YET BEEN VERIFIED.

REFERENCE(S)

1. BASEDATA MNRF 2016 AND CANVEC 2016
2. IMAGERY: © 2010 DIGITALGLOBE IMAGE COURTESY OF USGS EARTHSTAR GEOGRAPHICS SIO © 2017 MICROSOFT CORPORATION
3. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE18N

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
BAT HABITAT AVAILABILITY AND DISTRIBUTION IN THE LSA AND SSA – APPLICATION CASE

CONSULTANT

Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	KS
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.6.7-10

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm

This page left intentionally blank

Survival and Reproduction

Little brown myotis, northern myotis and tri-colored bat are already impaired at a population level in the Base Case due to the devastating effects of WNS at hibernacula. There will be no direct mortality of bats as a result of the NSDF Project, as the largest potential cause of mortality, removal of trees containing maternity roosts with juveniles that are not yet mobile, has been avoided through clearing outside of the period when roosts are occupied.

Sensory effects of noise and vibration from industrial activities (i.e., construction and operation of the NSDF Project) has the potential to affect bat survival by altering their ability to effectively carry out echolocation (Mackay and Barclay 1989; Schaub et al. 2008; Siemer and Schaub 2011). Available research has not resulted in definition of measurable thresholds that may negatively affect bat activity (e.g., dB levels). Because bats are highly mobile, they are able to avoid areas with elevated noise. The creation of noise therefore likely represents more of an effect on habitat availability, if the noise causes bats to avoid previously occupied maternity roost habitat that is in or around areas with high noise levels (see Habitat Availability discussion above). Habitat availability is likely not limiting for bat species that already occur below carrying capacity because of WNS.

5.6.7.5.2 Prediction Confidence

The assessment of effects on bats incorporates high uncertainty with regard to the existing conditions in the Base Case. Specifically, the presence and relative importance of roosting habitat in the LSA is uncertain. Data are unavailable to confirm roosting occurs in the LSA and the relative importance of the potential roost trees that may be affected by the NSDF Project is uncertain because the amount of roosting habitat required to support bat populations has not been established (COSEWIC 2013). This uncertainty was addressed by making precautionary assumptions about the amount of maternity roost habitat present within the RSA, LSA and SSA, and most likely over-estimating the amount of habitat and the number of roosting bats that could be supported.

The assumption that all mature forested areas provide maternity roost habitat, and at an equal distribution across the landscape represents a conservative over-estimate of actual occupancy and maternity roost presence in the forested area to be removed by the NSDF Project within the SSA, which are more likely to be in clumped distribution, if present. Roost selection at the forest stand scale is dependent on a number of factors which include the gaps in canopy cover, number of available snags, tree density, and proximity to water bodies (Environment Canada 2015b). Specific areas of uncertainty are described below.

There have been no netting, tracking or roost emergence counts performed in the RSA to-date, and no visual surveys conducted within the SSA to confirm occupancy of snags and to verify the presence of maternity roosts within the area to be cleared. Presence / not-detected information on the bat species in the RSA, LSA and SSA is based solely on acoustic monitoring results from two seasons of monitoring (2015 and 2016). The acoustic monitoring data from 2015 is exclusively from the CRL main campus and provides no indication of habitat use in the LSA or SSA. The 2016 acoustic monitoring surveys were conducted across the RSA, with three detector locations within the LSA, and one within the SSA.

The availability and distribution of maternity roosting habitat within the RSA has been based on vegetation community data, that itself is primarily based on a relatively old spatial dataset. There are attendant levels of error in using spatial data that has not undergone a high degree of ground-truthing; however, the filter used to determine potential maternity roost habitat was relatively coarse and simplified (i.e., mature forest of all types), so there is lower potential for error.

5.6.7.5.3 Residual Effects Classification

A summary of the classification of incremental adverse residual effects of the NSDF Project on bats in the Application Case is provided for each indicator in Table 5.6.7-11. Residual effects were described after the implementation of effective mitigation (Section 5.6.8.5.1), and summarized according to direction, magnitude, geographic extent, duration/reversibility, frequency/timing, and likelihood of the effect occurring following the methods described in Section 5.6.6.3 and the definitions provided in Table 5.6.6-1.

Table 5.6.7-11: Classification of Residual Effects on Bats in the Application Case

Indicator	Characteristic	Rating/Effect Size
Habitat Availability	Direction	Negative
	Magnitude	Direct loss of 25 ha of potential maternity roosting habitat (2% of RSA Base Case or 31% of LSA Base Case); potential avoidance of adjacent maternity roosting habitat due to sensory disturbance in the LSA
	Geographic Extent	Local
	Duration/Reversibility	Permanent (direct habitat loss)/Irreversible; Medium-term (sensory disturbance)
	Frequency/Timing	Continuous
	Likelihood	Probable (direct habitat loss and avoidance of maternity roosting habitat)
Habitat Distribution	Direction	Negative
	Magnitude	Creation of a gap in potential maternity roost habitat but overall a negligible change in movement corridors between maternity roosting habitat patches due to high mobility of species and relatively small gap created in area with high forest cover
	Geographic Extent	Local
	Duration/Reversibility	Permanent/Irreversible
	Frequency/Timing	Continuous
	Likelihood	Possible
Survival/ Reproduction	Direction	Neutral
	Magnitude	n/a
	Geographic Extent	n/a
	Duration/Reversibility	n/a
	Frequency/Timing	n/a
	Likelihood	Possible

Note: If a net effect was identified as positive or neutral, no additional effects characteristics, other than probability of occurrence were summarized.

ha = hectares; LSA = local study area; RSA = regional study area; n/a = Not applicable.

5.6.7.5.4 Determination of Significance

Populations of little brown myotis, northern myotis and tri-colored bats that overlap the RSA are highly sensitive to changes in survival and reproduction because WNS has resulted in dramatic declines of these species across the eastern portions of their Canadian range, which includes the RSA. Because of their rapidly declining populations, these species are more vulnerable to additional threats, including changes in habitat availability, distribution, or other factors affecting the survival and reproduction of the remaining individuals (Environment Canada 2015a). Therefore the existing level of pressure on these bat species in the Base Case has likely already exceeded their resilience and adaptability limits.

The grouping behaviour shown by bats in maternity roosts also makes them more sensitive to the loss of certain habitat features because the removal of relatively small numbers of habitat features, such as snags, can have a disproportionately large effect on local populations, if large numbers of bats previously congregated in snags that will be permanently removed. However, because WNS is such a strong limiting factor that overrides other potential causes of decline, maternity roosting habitat availability is not likely a limiting factor, at least not in places where such habitat is abundant, such as within the RSA. In the RSA, relatively undisturbed, mature forest stands are available and interspersed with numerous small lakes and wetland areas, which represent high quality and widely available foraging habitat.

All three species are inherently resilient to changes in their habitat based on their high degree of mobility, and one of the three species, little brown myotis, is well adapted to human disturbance, commonly using human structures for maternity roosting habitat. Northern myotis have been recorded to roost in bat boxes (Whitaker et al. 2006), and tri-colored bats will possibly roost in anthropogenic structures, but not as commonly as little brown myotis.

Rapid declines in abundance due to WNS may have already exceeded the resilience and adaptability limits of bats in the Base Case. Therefore, at Base Case, little brown myotis, northern myotis and tri-colored bat populations that overlap with the RSA are considered unlikely to be self-sustaining or ecologically effective. Consequently, the cumulative effects of existing disturbance and especially the introduced WNS are considered significant at Base Case.

In the Application Case, the NSDF Project will contribute a small incremental effect to this existing significant adverse cumulative effect. Importantly, because vegetation clearing will be undertaken outside of the maternity roosting season, no mortality of roosting bats is expected as a result of the NSDF Project and effects or the NSDF Project to survival and reproduction are considered neutral (Section 5.6.8.5.2). The NSDF Project footprint will permanently remove 25 ha of potential maternity roosting habitat. This represents 31% of available maternity roosting habitat in the LSA and 2% in the RSA. Additional areas of roosting habitat in the LSA that are immediately adjacent to the SSA may also be avoided due to sensory disturbance during construction and operation of the NSDF Project. The NSDF Project may also result in changes in local movement patterns, created by a widening of the existing gaps in the forest canopy created by East Mattawa Road and the two hydroelectric corridors, and installation of a six foot high perimeter fence. These local-scale changes are not expected to alter the extent of populations that overlap with the RSA because bats are highly mobile and capable of long commute distances, well beyond the boundaries of the RSA. The remaining availability of potential maternity roosting habitat in the Application Case is not likely a limiting factor in the RSA. Therefore, the contribution of the NSDF Project to the existing significant adverse cumulative effect to bats is predicted to be minor.

5.6.7.6 Blanding's Turtle

5.6.7.6.1 Residual Effects Analysis

Habitat Availability

The NSDF Project is estimated to remove 22 ha of proposed critical habitat for Blanding's turtle, which represents a loss of 13.3% of the proposed critical habitat in the LSA and 0.8% of the proposed critical habitat in the RSA (Table 5.6.7-12). The direct removal of 22 ha is upland habitat that Blanding's turtles use for movement, foraging, nesting, thermoregulation, and summer inactivity.

Table 5.6.7-12: Changes to Blanding's Turtle Critical Habitat and Potential Habitat Availability in the Application Case

Habitat Suitability	Regional Study Area				Local Study Area			
	Base Case [ha]	Application Case [ha]	Change in Area [ha]	Percent Change [%]	Base Case [ha]	Application Case [ha]	Change in Area [ha]	Percent Change [%]
Proposed Critical Habitat	2,788	2,766	-22	-0.8	168	145	-22	-13.3
Potential Critical Habitat	571	571	0	0.0	0	0	0	0.0
Non-critical Habitat	493	515	22	4.5	35	57	22	64.1

ha = hectare; % = percent.

Sensory disturbance (e.g. noise, light) during construction, operation and closure phases could indirectly reduce Blanding's turtle habitat availability in the LSA if Blanding's turtles avoid areas adjacent to the NSDF Project. The population of turtles using the RSA has likely adapted somewhat to the current level of activity in the RSA. Nesting in active sand and gravel pits as well as roadside occurrences of this species are not uncommon (Environment Canada 2016a), which suggests they can tolerate some level of anthropogenic sensory disturbances. The incremental increase in noise and light caused by the NSDF Project is not predicted to have a measurable effect on the behaviour of Blanding's turtles in adjacent habitats (such as Perch Lake). Vibrations from blasting activities in the SSA are expected to meet the DFO guidelines for protection of fish and it is anticipated that this protection will also extend to turtles when they are under water. Additionally, Blanding's turtles will be excluded from access to the SSA, so it is not anticipated that vibrations from activities within the SSA will have an effect on Blanding's turtles.

Changes to proposed critical habitat availability for Blanding's turtles as a result of the NSDF Project are certain because there will be a direct loss of 22 ha of proposed critical habitat (specifically habitat that may be used for nesting that occurs adjacent to wetlands). Effects will occur at the site scale. Effects from direct habitat loss will be continuous and permanent. Effects from sensory disturbance are not expected to be measurable, but any minor effects that might occur would be reversible over the long-term.

The destruction of proposed critical habitat for the Blanding's turtle will require a permit under Section 73 of SARA. ECCC issues permits for activities affecting species listed on Schedule 1 of SARA on a case by case basis. CNL is in on-going engagement with ECCC regarding this SAR and the management of the site and consequent protection and conservation of the population and its habitats.

Habitat Distribution

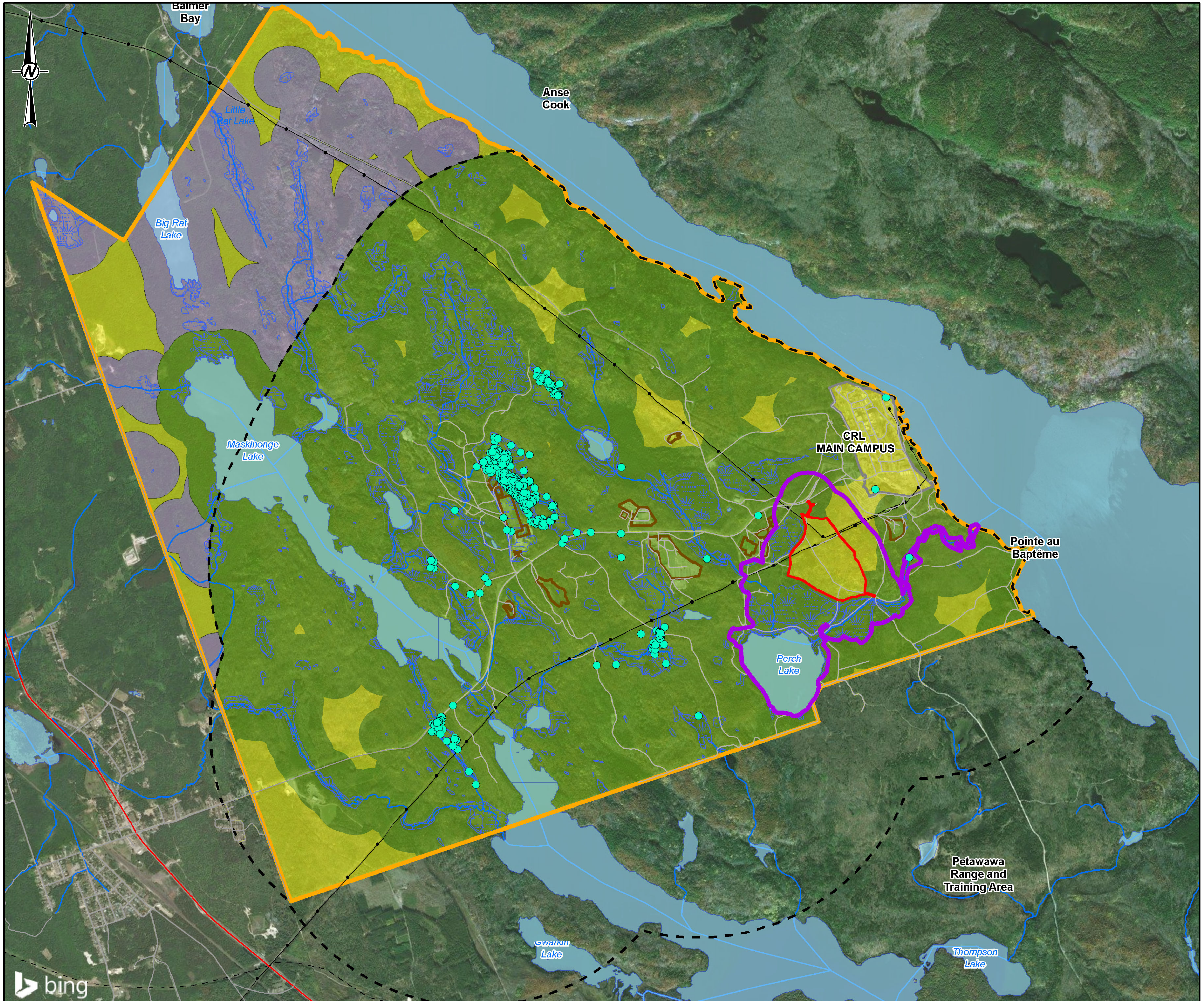
The development of the NSDF Project will have a minor effects on proposed critical habitat distribution and connectivity for Blanding's turtle in the RSA. Proposed critical habitat and potential critical habitat remains abundant and well connected in the RSA in the Application Case, (Figure 5.6.7-11). The NSDF Project will use many existing roads instead of creating new ones, and road upgrades will occur at the local scale.

The main Blanding's turtle migration corridors will remain intact within the LSA and RSA. In particular, the wetland complexes which are likely the principal movement routes will remain in their existing condition and the NSDF Project will not alter their connectivity. The NSDF Project is surrounded by wetlands that are known to provide habitat for Blanding's turtles (Figure 5.6.7-12) and there are some areas within the SSA and LSA that have the potential to be nesting habitat for Blanding's turtle. The development of the NSDF Project will alter Blanding's turtle movement patterns and access to potential nesting habitat in the SSA. This species shows site fidelity to wetlands that are used as overwintering habitat and to areas that are used for nesting year after year. Therefore, the movements of this species from overwintering areas to nesting areas will be disrupted by the development of the NSDF Project. In particular, the SSA will be surrounded by a fence that will exclude wildlife including Blanding's turtles from accessing the site, requiring individuals to travel around the outside of the fence if they need to move around the NSDF Project to reach locations they require to carry out their life history requirements such as foraging, thermoregulation, nesting, etc. If Blanding's turtles use the SSA as a movement corridor between habitats, the NSDF Project will increase travel distances.

Effects on Blanding's turtle from changes to habitat distribution are certain because the NSDF Project footprint will alter the movement of turtles in the LSA. Effects will be continuous and permanent because the development of the NSDF Project will result in the permanent reconfiguration of habitat on the landscape.

This page left intentionally blank

232 509220 REPT 004
UNRESTRICTED



LEGEND

- HIGHWAY
- ROAD
- TRANSMISSION LINE
- NATURAL GAS PIPELINE
- RIVER/STREAM
- WATERBODY
- WETLAND
- CRL MAIN CAMPUS
- WASTE MANAGEMENT SITES (WMA)[1]
- REGIONAL STUDY AREA (CRL PROPERTY)
- LOCAL STUDY AREA
- SITE STUDY AREA (NSDF PROJECT SITE)
- BLANDING'S TURTLE OBSERVATION
- BLANDING'S TURTLE PROPOSED CRITICAL HABITAT
- BLANDING'S TURTLE POTENTIAL HABITAT
- BLANDING'S TURTLE UNSUITABLE HABITAT
- BLANDING'S TURTLE OBSERVATION 2 km RADIUS

1 0 1
1:35,000 KILOMETRES

NOTE(S)
1. LIQUID DISPOSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.

REFERENCE(S)
1. BASEDATA MNRF 2016 AND CANVEC 2016
2. IMAGERY: © 2017 DIGITALGLOBE IMAGE COURTESY OF USGS EARTHSTAR GEOGRAPHICS SIO © 2017 MICROSOFT CORPORATION
3. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE18N

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
BLANDING'S TURTLE HABITAT AVAILABILITY AND DISTRIBUTION IN THE RSA – APPLICATION CASE

CONSULTANT
Golder Associates

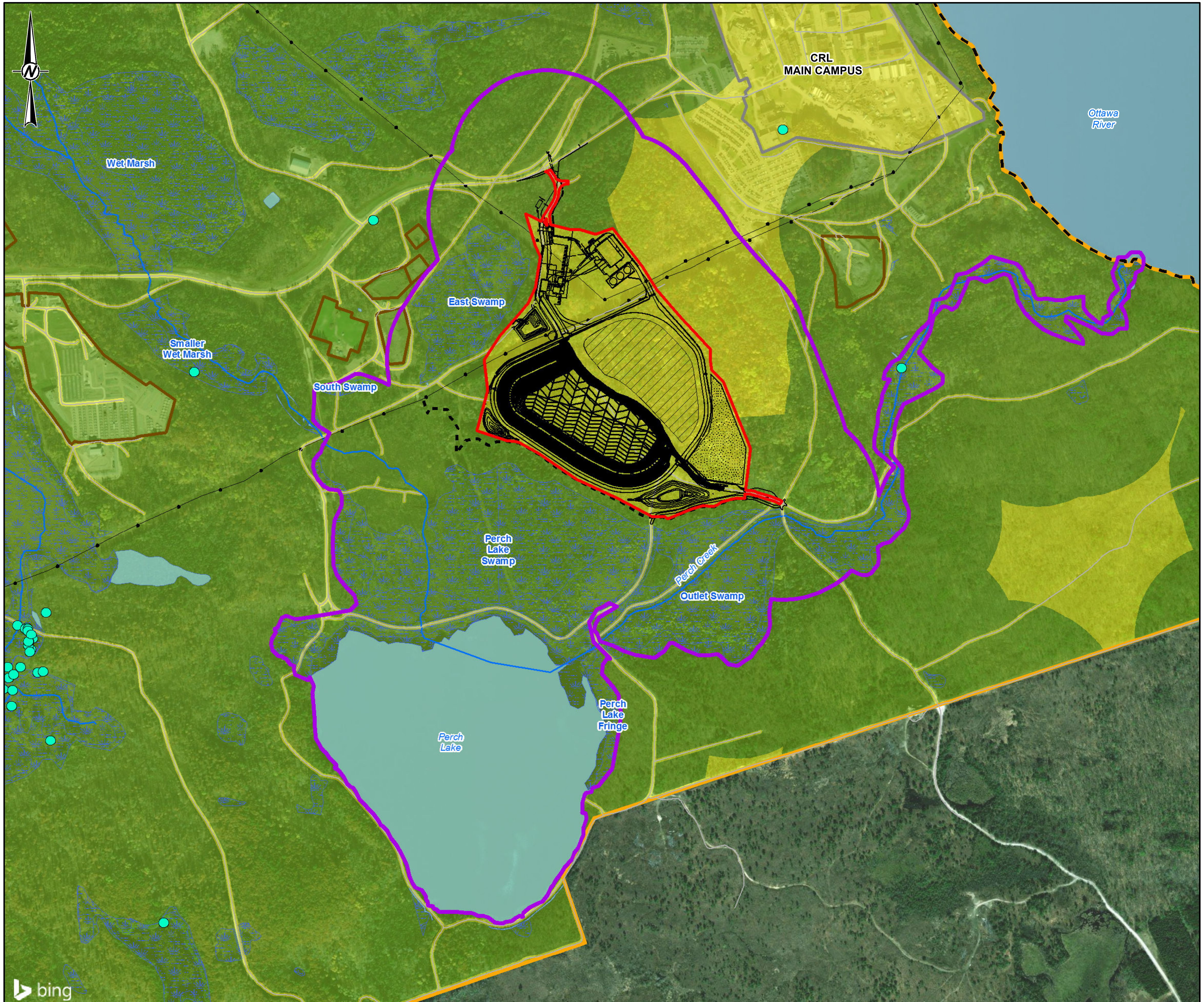
YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	EG
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.6.7-11

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:
25mm

This page left intentionally blank

232-509220-REPT-004
UNRESTRICTED



LEGEND

- HIGHWAY
- ROAD
- TRANSMISSION LINE
- RIVER/STREAM
- WATERBODY
- WETLAND
- FENCE
- INFRASTRUCTURE
- LAYDOWN AREA
- STOCKPILE
- CRL MAIN CAMPUS
- WASTE MANAGEMENT AREA (WMA)[1]
- REGIONAL STUDY AREA (CRL PROPERTY)
- LOCAL STUDY AREA
- SITE STUDY AREA (NSDF PROJECT SITE)
- BLANDING'S TURTLE OBSERVATION
- BLANDING'S TURTLE PROPOSED CRITICAL HABITAT
- BLANDING'S TURTLE UNSUITABLE HABITAT
- BLANDING'S TURTLE OBSERVATION 2 km RADIUS

250 0 250

1:10,000 METRES

NOTE(S)

1. LIQUID DISPOSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.

REFERENCE(S)

1. BASEDATA MNRF 2016 AND CANVEC 2016
2. IMAGERY: © 2010 DIGITALGLOBE IMAGE COURTESY OF USGS EARTHSTAR GEOGRAPHICS SIO © 2017 MICROSOFT CORPORATION
3. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE18N

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
BLANDING'S TURTLE HABITAT AVAILABILITY AND DISTRIBUTION IN THE LSA AND SSA – APPLICATION CASE

CONSULTANT

Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	EG
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.6.7-12

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm

This page left intentionally blank

Survival and Reproduction

Site clearing is not expected to cause Blanding's turtle mortality because it will be performed in the winter when individuals are hibernating and no wetlands (i.e., potential hibernating habitat) will be affected. Reptile exclusion fencing will be installed surrounding the perimeter of the site and remain in place for the life of the NSDF Project to avoid having Blanding's turtles access the active site and become at risk of injury or mortality. Therefore, effects on Blanding's turtle survival from NSDF Project activities within the fenced perimeter are neutral.

As the SSA supports Blanding's turtle proposed critical habitat, specifically upland habitat adjacent to wetlands which has the potential to be nesting habitat, the permanent loss of proposed critical habitat due to the NSDF Project is predicted to result in a change in reproductive success until the females using this habitat find new nesting areas. Effects on Blanding's turtle reproduction from the loss of proposed critical habitat are probable at the local scale. Effects from habitat loss are anticipated to be continuous and permanent.

Road mortality is one of the main threats to Blanding's turtles and is thought to lead to population declines for this species. Increased traffic as a result of the NSDF Project has the potential to injure or kill Blanding's turtles. East Mattawa Road will be upgraded in order to accommodate the traffic going to and from the ECM. Traffic to the SSA during construction will predominantly be from Plant Road to East Mattawa Road and during operations will predominantly be from Dump Road to East Mattawa Road. A comprehensive road mitigation plan will be developed for the NSDF Project which will entail an assessment of the road segments within the NSDF Project footprint (East Mattawa Road upgrades) as well as the roads in the LSA which pose a risk to Blanding's turtle mortality (i.e., Dump Road and portions of Plant Road that will be used to transport materials to the NSDF Project footprint; PAB Road that runs parallel to the Perch Creek Wetland corridor; and the section of East Mattawa Road that crosses Perch Creek Wetland). Areas of high risk for Blanding's turtles crossing will be determined using roadkill data, knowledge of habitat use and behavioural traits. For instance, wetlands are natural movement corridors for this species. It is likely that individuals move from the Perch Lake area, north through the wetlands that cross Plant Road, or east through the wetlands that extend along Perch Creek, which flows under East Mattawa Road. It will be determined if there are existing suitable crossing structures under the roads in these high risk areas or whether there needs to be upgrades or the creation of new crossing structures. Permanent fencing similar to reptile exclusion fencing or other suitable alternative, will be installed to direct turtles towards culverts under the road for safe crossing. The extent of fencing will be site specific and determined through the road mitigation assessment. Regular monitoring and maintenance of the fencing and the passages will allow for detection of gaps, improperly functioning sections and affirm species usage of crossing structures. Other mitigation measures such as driver's training, low speed limit, and speed bumps will be considered to reduce the road mortality for the species and developed in conjunction with ECCC. If these road mitigation techniques are effective then the risk of road mortality on Blanding's turtle from the increased traffic associated with the NSDF Project over the lifetime of the NSDF Project will be reduced and potentially eliminated. Effects on Blanding's turtle survival and reproduction from road mortality are possible at the local scale. Effects from road mortality due to the NSDF Project are anticipated to be infrequent and reversed at the end of operations (long-term).

5.6.7.6.2 Prediction Confidence

The residual effects assessment for Blanding's turtle is based on an adequate knowledge of the species' life history characteristics and some understanding of the sensitivities of populations of long-lived organisms to anthropogenic disturbance.

CNL has conducted surveys for Blanding's turtles, which have resulted in observations of individual Blanding's turtles and confirmation of some hibernation habitat in the RSA and LSA. There is high confidence that a Blanding's turtle population is present in the RSA and a high likelihood that they use the LSA. However, their use of the SSA has not been confirmed and the location of suitable nesting habitat in the RSA, LSA and SSA has not been confirmed. The use of the habitat within the SSA by Blanding's turtles is not known. This assessment used a precautionary approach to manage uncertainty and assumed that nesting habitat was present in the SSA. This approach may have resulted in an overestimation of the potential effects of the NSDF Project on Blanding's turtles. As part of the SARA permit process for the removal of proposed critical habitat, ECCC will require the identification and mapping of Blanding's turtle habitats within the SSA in order to characterize the habitat loss and determine site specific actions to be taken to compensate for the habitat loss due to the Project.

Until it is developed and monitored, the effectiveness of the road mitigation plan remains unknown. However, other road mitigation plans for this species have been observed to be effective in keeping turtles off the road and reducing road kill. Therefore, this mitigation has a moderate level of certainty.

There is a high level of uncertainty associated with the long-term conservation prospects for the Great Lakes/ St. Lawrence population of Blanding's turtle. Evidence suggests that populations are declining across the species' range in Canada. If the declining population trend is not reversed or accelerates over the next decade, then Blanding's turtle may be up-listed from threatened to endangered.

5.6.7.6.3 Residual Effects Classification

A summary of the classification of incremental adverse residual effects of the NSDF Project on Blanding's turtle in the Application Case is provided for each indicator in Table 5.6.7-13. Residual effects were described after the implementation of effective mitigation, and summarized according to direction, magnitude, geographic extent, duration/reversibility, frequency/timing, and likelihood of the effect occurring following the methods described in Section 5.6.6.3 and the definitions provided in Table 5.6.6-1.

Table 5.6.7-13: Description of Residual Effects on Blanding's Turtle in the Application Case

Indicator	Characteristic	Rating/Effect Size
Habitat Availability	Direction	Negative
	Magnitude	Direct loss of 22 ha of proposed critical habitat (0.8% in RSA, 13.3% in LSA), specifically habitat that may be used for nesting by Blanding's turtles
	Geographic Extent	Project Footprint
	Duration/Reversibility	Permanent
	Frequency/Timing	Continuous
	Likelihood	Certain
Habitat Distribution	Direction	Negative
	Magnitude	Change in movement corridors between habitat patches due to development of the NSDF Project
	Geographic Extent	Local
	Duration/Reversibility	Permanent
	Frequency/Timing	Continuous
	Likelihood	Probable

Table 5.6.7-13: Description of Residual Effects on Blanding's Turtle in the Application Case

Indicator	Characteristic	Rating/Effect Size
Survival and Reproduction	Direction	Negative
	Magnitude	Change in reproductive success due to loss of nesting habitat; increased risk of injury/mortality on roads
	Geographic Extent	Local
	Duration/Reversibility	Medium-term (loss of nesting habitat); Permanent (road kill)
	Frequency/Timing	Infrequent (loss of nesting habitat); Infrequent (road kill)
	Likelihood	Possible

5.6.7.6.4 Determination of Significance

The population of Blanding's turtles that overlaps with the RSA is considered highly sensitive to changes in habitat availability, distribution, and survival and reproduction. Two of the primary threats (noted as the highest levels of concern) to this species are land conversion and road networks (Environment Canada 2016a). Blanding's turtles display fidelity to hibernation and nesting habitat and therefore its elimination can result in long distance travel in search of new habitat and the use of lower quality habitat. A total of 168 ha and 2,788 ha of proposed critical habitat for Blanding's turtle is estimated to be present in the LSA and RSA, respectively, in the Base Case. An additional 571 ha of potential critical habitat is estimated to be present in the RSA. Hibernation habitat has been confirmed in several wetlands/waterbodies in the RSA and the LSA. Likely nesting habitat occurs throughout the LSA and RSA in numerous sandy outcrops that CNL has noted. In particular, there is some potential within the hydroelectric corridors that run through the study areas, the sandy outcrop adjacent to Perch Lake and the sand dunes at Pointe au Baptême. However, nesting locations have not yet been confirmed. Movement corridors likely exist through wetlands such as the Perch Creek riparian corridor and the north-south trending wetlands across Plant Road. Roadkill is a particular concern to the survival and reproduction of this species as it has low rates of recruitment and population growth. Two individuals from this population have been killed on the roads within the RSA in the last five years.

In the Application Case, the NSDF Project footprint would permanently remove 22 ha of proposed critical habitat during construction. This permanent loss of upland habitat within the SSA has the potential to be used for nesting, thermoregulation and summer inactivity. Females who use the SSA for nesting may experience a reduction in reproductive success until they find new areas within which to nest. Additionally, females may need to travel greater distances if the availability of new nesting sites is limited and/or use lower quality habitats. The use of lower quality habitats could affect hatchling success rates. In searching for new habitats, individual Blanding's turtles may become exposed other risks (e.g. roads).

The NSDF Project will result in a change in movement patterns at the local scale. The interruption or barrier to Blanding's turtles moving through the SSA will result in the need to travel longer distances around the SSA in search of resources and will increase their risk of injury or mortality on roads. The increase in traffic related to the NSDF Project and consequently the risk of road injury or mortality will be mitigated through a comprehensive road mitigation plan, however the risk of road mortality, albeit reduced still remains.

The mortality of adult turtles, specifically mature females, decreases recruitment and long-term sustainability of subpopulations (Congdon et al. 1993; Environment Canada 2016a). High adult survivorship rates are a key trait of turtle biology. A long-term demographic study of a Blanding's turtle population on the E.S. George Reserve in Michigan, indicates that modest increases (2-3%) in annual adult mortality is likely more than this species can absorb and still maintain positive population growth rates (Congdon et al. 1993). Therefore, if this effect goes unmitigated or improperly mitigated and Blanding's turtle mortality increases due to the NSDF Project, then this could have a significant effect on the sustainability of the population that overlaps with the RSA. Concerted efforts to reduce the risk of mortality among juveniles and adults of the population that overlaps the RSA is required and will be implemented on the CNL site to enhance the chance of survival for this population.

Overall, there are many environmental effects of primary concern (i.e., habitat loss, habitat fragmentation and road mortality) impacting this population of Blanding's turtle from the NSDF Project and from previous and existing activities and developments. It is possible that the level of habitat fragmentation and road mortality existing on the CNL site are significantly impacting this population in the Base case at an unsustainable rate. Consequently, cumulative effects from the NSDF Project and previous and existing activities and developments in the RSA on the Blanding's turtle population that overlaps with the RSA are predicted to be significant in the Application Case.

5.6.8 Monitoring and Follow-up

This section of the EIS provides the conceptual outline for any monitoring and follow-up programs recommended to confirm the predictions made in the terrestrial biodiversity assessment (Table 5.6.8-1). Monitoring programs recommended for Canada warbler, eastern whip-poor-will, golden-winged warbler, bats, and Blanding's turtle will be integrated into CNL's existing Species at Risk program.

Table 5.6.8-1: Monitoring and Follow-up Programs for Terrestrial Biodiversity

Valued Component	Project Phase and Potential Effects	Monitoring Program Objective	Conceptual Monitoring/ Follow up Program	Suggested Duration	Implementing Program
Canada warbler	■ **Habitat Availability**: Permanent, direct loss of 25 ha of suitable habitat. Long-term reduction in quality of nesting habitat and possible avoidance in the LSA from sensory disturbance. ■ **Habitat Distribution**: Small, permanent change in local movement ■ **Survival and Reproduction**: Small reduction in reproductivity from sensory disturbance	Verify EA predictions through collection of data on relative abundance and other key demographic parameters for breeding bird populations that overlap with the RSA	Data on relative abundance and other key demographic parameters for breeding birds in the RSA will be used to evaluate trends in populations of breeding birds that overlap with the RSA, including Canada warbler, eastern whip-poor-will and golden-winged warbler. If declining trends are observed for these species in the RSA, then the need for additional mitigation measures will be evaluated in consultation with ECCC.	Every 5 years	Monitoring Avian Productivity and Survivorship (MAPS) Program is integrated into CNL's existing Species at Risk program
Eastern whip-poor-will	■ **Habitat Availability:** Permanent, direct loss of 1 ha of suitable habitat ■ **Habitat Distribution**: Small, permanent change in local movement ■ **Survival and Reproduction**: Small reduction in reproductivity from sensory disturbance				
Golden-winged warbler	■ **Habitat Availability:** Permanent, direct loss of 24 ha of suitable habitat ■ **Habitat Distribution**: Small, permanent change in local movement ■ **Survival and Reproduction**: Small reduction in reproductivity from sensory disturbance				

Table 5.6.8-1: Monitoring and Follow-up Programs for Terrestrial Biodiversity

Valued Component	Project Phase and Potential Effects	Monitoring Program Objective	Conceptual Monitoring/ Follow up Program	Suggested Duration	Implementing Program
Bats	■ **Habitat Availability:** Permanent, direct loss of 25 ha of potential maternity roosting habitat ■ **Habitat Distribution:** Gap in potential maternity roosting habitat, but negligible change in local movement patterns ■ **Survival and Reproduction:** No residual effects due to the NSDF Project	■ Offset the incremental contribution of the NSDF Project to the loss of potential maternity roosting habitat in the SSA ■ Verify effectiveness of mitigation by determining number of individuals and species of bats using boxes for roosting habitat	■ Inherent uncertainty on the current status of bat populations overlapping the RSA and uncertainty regarding the amount and relative importance of maternity roost habitat that will be lost as a result of the NSDF Project is the main rationale for installing bat boxes as mitigation / off-setting. Further, CNL is planning to remove over 100 buildings in the built-up area that potentially host bat species either during the breeding season or during hibernation, and installing additional bat boxes at the NSDF Project is intended to also offset the future removal of these anthropogenic structures. ■ Offsetting the removal of unoccupied bat maternity roost trees is not required under SARA; however, bat boxes are relatively inexpensive and can be highly effective at providing habitat for roosting little brown myotis and possibly northern myotis. Tri-colored bats are less likely to use bat boxes, but may use other forms of artificial roosting habitat; these options may be considered. Installation of bat boxes in suitable locations in the RSA is recommended to offset the incremental contribution of the NSDF Project to cumulative effects on SARA-listed bats. ■ In consultation with CNL biologists, and in consideration of future losses of anthropogenic structures that may provide roosting habitat, offsetting in the form of 16 bat boxes is recommended. Each 4-chambered box (Bat Conservation International approved design) will be installed back-to-back on galvanized steel poles (galvanized steel to reduce predator access). These will require installation at a total of 8 locations (2 boxes per pole, per location). This box design is suggested to have capacity for 350-400 individual bats per house, providing roosting habitat for a potential maximum of 6400 individual bats (with 16 boxes). ■ Criteria for appropriate siting will include: accessibility of box locations for installation and future monitoring of utilization / effectiveness, avoidance of areas with radiological contamination in surface water features, and appropriate distance to anthropogenic disturbances to avoid sensory effects (i.e., noise). Immature forested areas adjacent to larger uncontaminated waterbodies and wetlands are high priority locations, because these forest types do not currently provide high quality roosting habitat and would be most benefited by installation of bat roost boxes to expand the spatial coverage of potential roosting habitat within the RSA. Final site selection will be at the discretion of CNL biologists. ■ Monitoring will be conducted to determine if boxes are being used. Boxes not being used may be moved to an alternate location.	Bat boxes should remain in place throughout Operations. Monitoring should take place annually for three years	Monitoring will be integrated into CNL's existing Species at Risk program
Blanding's turtle	■ **Habitat Availability:** Direct, permanent loss of 22 ha of critical habitat ■ **Habitat Distribution:** Permanent change in local movement ■ **Survival and Reproduction:** Reduced reproductive success and mortality of individuals over the lifespan of the NSDF Project	Confirm effectiveness of mitigation through tracking wildlife mortality and use information for adaptive management	Wildlife-vehicle collision monitoring – Vehicle-caused Blanding's turtle mortality will be reported and data will be compiled in a database that can be used to inform adaptive management for the site.	On-going during Construction and Operations and Closure	Monitoring will be integrated into CNL's existing Species at Risk program
		Confirm effectiveness of road mitigation to minimize or eliminate the potential for road mortality in the LSA	Road mitigation plan – Comprehensive assessment of high risk crossing locations for Blanding's turtles. Consideration of the location and type of existing crossing culverts as passageways or upgrade or install new crossing structures that are conducive to Blanding's turtle safe passage under the roads. Install permanent fencing on either side of the roadway at these crossing locations to funnel turtles into the passage culvert and prevent them from going on the road. Monitor the fencing to identify gaps or improperly functioning sections to be repaired. Monitoring the culvert passages to determine if Blanding's turtles are using the culvert passages to cross under the road. Install remote cameras within the culverts to determine their usage.	On-going during Construction and Operations and Closure	Monitoring will be integrated into CNL's existing Species at Risk program

5.6.9 Conclusions

Valued components refer to environmental features that may be affected by a project and that have been identified to be of concern by the proponent, scientists, government agencies, First Nation and Métis peoples, or the public (The Agency 2014). Selection of VCs for the terrestrial biodiversity assessment was accomplished using a coarse and fine filter approach. Coarse filter VCs were identified to permit an assessment of the effects of the NSDF Project to terrestrial biodiversity broadly, whereas fine filter VCs focus the assessment on individual biodiversity features, such as species. Combined, the coarse and fine filter VCs are selected to provide a holistic assessment of the potential effects of the NSDF Project on terrestrial biodiversity.

All SARA-listed species with confirmed observation records within the CRL property were considered as potential VCs at the species level. Species with a very low likelihood of occurrence in the LSA, for which habitat was not present in the LSA, or for which effects of the NSDF Project were unlikely, were excluded as VCs. Rationale for inclusion and exclusion of each species at risk identified during surveys undertaken in the CRL property is presented in Appendix 5.6-1.

The VCs selected for the terrestrial biodiversity assessment were: vegetation communities, migratory birds, Canada warbler, eastern whip-poor-will, golden-winged warbler, bats, and Blanding’s turtle. The assessment endpoint for terrestrial biodiversity is the maintenance of self-sustaining and ecologically effective vegetation communities or wildlife populations. Ecosystem availability, ecosystem distribution, and ecosystem composition were selected as the measurement indicators for the vegetation communities VC. Habitat availability, habitat distribution, and survival and reproduction were selected as the measurement indicators for the terrestrial biodiversity species VCs.

Residual effects to terrestrial VCs are primarily associated with vegetation clearing and grubbing and the associated loss or alteration of existing vegetation and topographical features; sensory disturbance from NSDF Project activities during construction and operations; and increased risk of injury/mortality on roads to Blanding’s turtle due to equipment and vehicle traffic.

The cumulative effects from the NSDF Project and previous and existing activities and developments in the RSA on the population of terrestrial biodiversity VCs that overlaps with the RSA are predicted to be not significant in the Application Case for all VCs, with the exception of bats and Blanding’s turtle. Populations of little brown myotis, northern myotis and tri-colored bats that overlap the RSA are highly sensitive to changes in survival and reproduction because WNS has resulted in dramatic declines of these species across the eastern portions of their Canadian range, which includes the RSA. Therefore, the existing level of pressure on these bat species in the Base Case has likely already exceeded their resilience and adaptability limits and they are unlikely to be self-sustaining or ecologically effective. Consequently, the cumulative effects of existing disturbance and especially the introduced WNS are considered significant at Base Case.

In the Application Case, the NSDF Project will contribute a small increment to this existing significant adverse cumulative effect. Importantly, because vegetation clearing will be undertaken outside of the maternity roosting season, no mortality of roosting bats is expected as a result of the NSDF Project and effects or the NSDF Project to survival and reproduction are considered neutral. In addition, the remaining availability of potential maternity roosting habitat in the Application Case is not likely a limiting factor in the RSA. Therefore, the contribution of the NSDF Project to the existing significant adverse cumulative effect to bats is predicted to be minor.

Offsetting the removal of unoccupied bat maternity roost trees is not required under SARA, however, installation of bat boxes in suitable locations in the RSA is recommended to mitigate the incremental contribution of the NSDF Project. Monitoring will be conducted to determine if boxes are being used.

In the Application Case, the NSDF Project footprint would permanently remove 22 ha of proposed Blanding's turtle critical habitat during construction. This permanent loss of upland habitat within the SSA has the potential to be used for nesting, thermoregulation and summer inactivity. Females who use the SSA for nesting may experience a reduction in reproductive success until they find new areas within which to nest. In addition, the interruption or barrier to Blanding's turtles moving through the SSA will result in the need to travel longer distances around the SSA in search of resources and will increase their risk of injury or mortality on roads. The increase in traffic related to the NSDF Project and consequently the risk of road injury or mortality will be mitigated through a comprehensive road mitigation plan, however the risk of road mortality, albeit reduced still remains.

It is possible that the level of habitat fragmentation and road mortality existing on the CNL site are significantly impacting the population of Blanding's turtle in the Base case at an unsustainable rate. Consequently, cumulative effects from the NSDF Project and previous and existing activities and developments in the RSA on the Blanding's turtle population that overlaps with the RSA are predicted to be significant in the Application Case.

The destruction of proposed critical habitat for Blanding's turtle will require a SARA permit under Section 73(3). In addition, a road mitigation plan will be developed that will include an assessment of high risk road crossing locations, and consideration of the type of passageways (e.g. culverts) that exist or require upgrading or replacement with new crossing structures that are conducive to Blanding's turtle safe passage under the roads. In addition, the existing CNL Employee Education Program will be adapted to the NSDF Project prior to construction. All employees and contractors will be trained on the identification and safe handling of Blanding's turtle in order to help the turtle across the road.

Table 5.6.9-1: Summary of Predicted Residual Adverse Effects for Terrestrial Biodiversity Valued Components

Valued Components	Assessment Endpoint	Residual Adverse Effects	Project Effect Occurs in	Contributing Project Activity	Proposed Mitigation	Significance
Vegetation Communities	Maintenance of self-sustaining and ecologically effective vegetation communities	■ Permanent loss of 30 ha of forested communities ■ Permanent changes to the distribution of forested habitats; no changes to the distribution of wetlands ■ Permanent edge effects may alter adjacent vegetation community richness	All phases	■ Vegetation clearing and grubbing	■ The NSDF Project footprint has been designed to avoid wetlands and limit disturbance to the natural environment to the extent feasible. For example, as the ECM is developed sequentially, undeveloped cells may be prepared and used as stockpile areas to store overburden soils to be used during construction or for daily/interim cover stockpiles. This approach reduces the required area for the laydown and stockpile of materials. ■ A 30 m buffer is established along all identified wetlands near the NSDF site. ■ A 5 m tree-line buffer is established from all property lines on the NSDF site in order to limit disturbance to vegetation and large tree roots at the tree-line	Not Significant
Canada Warbler	Maintenance of self-sustaining and ecologically effective populations	■ Permanent loss of 25 ha of suitable habitat ■ Possible long-term avoidance in the LSA from sensory disturbance ■ Permanent small change in movement in the LSA ■ Permanent small reduction in carrying capacity	All phases	■ Vegetation clearing and grubbing ■ Mobilization of equipment ■ Hauling of materials ■ Blasting	■ The NSDF Project footprint has been designed to avoid wetlands and limit disturbance to the natural environment to the extent feasible. For example, as the ECM is developed sequentially, undeveloped cells may be prepared and used as stockpile areas to store overburden soils to be used during construction or for daily/interim cover stockpiles. This approach reduces the required area for the laydown and stockpile of materials. ■ A 30 m buffer is established along all identified wetlands near the NSDF site. ■ A 5 m tree-line buffer is established from all property lines on the NSDF site in order to limit disturbance to vegetation and large tree roots at the tree-line ■ Avoid conducting the activities with highest levels of noise and habitat disturbance during most sensitive life history phase (i.e., breeding and nesting for birds, maternity roosting for bats) by conducting vegetation clearing and grubbing before April 8, or after August 31 to avoid effects on nesting birds.	Not Significant
Eastern Whip-poor-will		■ Permanent loss of 1 ha of suitable habitat ■ Possible long-term avoidance in the LSA from sensory disturbance ■ Permanent small change in movement in the LSA ■ Permanent small reduction in carrying capacity				Not Significant
Golden-winged Warbler		■ Permanent loss of 24 ha of suitable habitat ■ Possible long-term avoidance in the LSA from sensory disturbance ■ Permanent small change in movement in the LSA ■ Permanent small reduction in carrying capacity				Not Significant

Table 5.6.9-1: Summary of Predicted Residual Adverse Effects for Terrestrial Biodiversity Valued Components

Valued Components	Assessment Endpoint	Residual Adverse Effects	Project Effect Occurs in	Contributing Project Activity	Proposed Mitigation	Significance
Bats	Maintenance of self-sustaining and ecologically effective populations	■ Permanent loss of 25 ha of high quality potential maternity roost habitat ■ Potential long-term avoidance of adjacent maternity roosting habitat in the LSA from sensory disturbance ■ Permanent negligible change in movement corridors between maternity roosting habitat patches	All phases	■ Vegetation clearing and grubbing ■ Mobilization of equipment ■ Hauling of materials ■ Blasting	■ The NSDF Project footprint has been designed to avoid wetlands and limit disturbance to the natural environment to the extent feasible. For example, as the ECM is developed sequentially, undeveloped cells may be prepared and used as stockpile areas to store overburden soils to be used during construction or for daily/interim cover stockpiles. This approach reduces the required area for the laydown and stockpile of materials. ■ A 30 m buffer is established along all identified wetlands near the NSDF site. ■ A 5 m tree-line buffer is established from all property lines on the NSDF site in order to limit disturbance to vegetation and large tree roots at the tree-line ■ Avoid conducting the activities with highest levels of noise and habitat disturbance during most sensitive life history phase (i.e., breeding and nesting for birds, maternity roosting for bats) by conducting vegetation clearing and grubbing before April 8, or after August 31 to avoid effects on bat maternity roosts.	Significant

Table 5.6.9-1: Summary of Predicted Residual Adverse Effects for Terrestrial Biodiversity Valued Components

Valued Components	Assessment Endpoint	Residual Adverse Effects	Project Effect Occurs in	Contributing Project Activity	Proposed Mitigation	Significance
Blanding's Turtle		■ Permanent loss of 22 ha of proposed critical habitat ■ Permanent change in movement corridors between habitat patches ■ Long-term increased risk of injury/mortality on roads from increased traffic ■ Permanent increased risk of mortality from changes to movement patterns	All phases	■ Vegetation clearing and grubbing ■ Mobilization of equipment ■ Hauling of materials ■ Installation and maintenance of perimeter fencing	■ The NSDF Project footprint has been designed to avoid wetlands and limit disturbance to the natural environment to the extent feasible. For example, as the ECM is developed sequentially, undeveloped cells may be prepared and used as stockpile areas to store overburden soils to be used during construction or for daily/interim cover stockpiles. This approach reduces the required area for the laydown and stockpile of materials. ■ A 30 m buffer is established along all identified wetlands near the NSDF site. ■ A 5 m tree-line buffer is established from all property lines on the NSDF site in order to limit disturbance to vegetation and large tree roots at the tree-line ■ Avoid conducting the activities with highest levels of noise and habitat disturbance during most sensitive life history phase (i.e., breeding and nesting for birds, maternity roosting for bats) by conducting vegetation clearing and grubbing before April 8, or after August 31 to avoid effects on the active Blanding's turtle season. ■ Install reptile exclusion fencing around perimeter of the NSDF Project site prior to initiating activities during the construction phase or prior to the active Blanding's turtle season (i.e., prior to April). ■ Repair damaged or ineffective fencing and signage. ■ Develop and implement a road mitigation plan for roads in the LSA (East Mattawa Road, Dump Road, PAB Road and Plant Road) including the location and design of passages for Blanding's turtles under roads and the extent of funnel fencing to direct individuals to the safe crossing structures. ■ Drivers have standard safety training and are provided with environmental awareness training. ■ Enforce existing CNL property speed limits on access roads. ■ Post signs warning drivers of high use wildlife areas and reduce speed limits in these areas. ■ Employees in vehicles encountering wildlife of concern (e.g., Blanding's turtle) on roads are required to communicate the presence of wildlife on the roads to other employees working in the area and to CNL's Environmental Staff. ■ The existing CNL Employee Education Program will be adapted to the NSDF Project prior to construction. All employees and contractors will be trained on the identification and safe handling of Blanding's turtle in order to help the turtle across the road. ■ As per CNL's Management of Land, Habitat, and Wildlife Procedure, dead or wounded animals on roads must be reported to the safety department. ■ Wildlife collisions with vehicles will be monitored, which provides feedback for adaptive management.	Significant

This page left intentionally blank

5.7 Ambient Radioactivity and Ecological Health

This section of the Environmental Impact Statement (EIS) for the Canadian Nuclear Laboratories (CNL) Near Surface Disposal Facility (NSDF) Project seeks to understand and characterize existing ambient radioactivity at the Chalk River Laboratories (CRL) property. The focus of this section is to summarize the results of the Environmental Risk Assessment (ERA), specifically as it relates to effects to ecological health (i.e., non-human biota) from changes in ambient radioactivity.

5.7.1 Scope of the Assessment

The ambient radioactivity and ecological health assessment follows the overall environmental assessment approach and methods described in Section 5.1 Environmental Assessment Methodology. The assessment is completed in the following key steps:

- **Step 1 – Identify Valued Components (VCs) and define the spatial boundaries, temporal boundaries, and assessment cases** for the ecological health assessment (refer to Sections 5.7.2 Valued Components and Section 5.7.3 Assessment Boundaries). The VCs and measurement indicators used to assess NSDF Project-related changes to ecological health, the spatial and temporal boundaries at which the assessment occurred, and the assessment cases considered are described.
- **Step 2 – Describe the existing conditions** (refer to Section 5.7.4 Description of the Environment). Existing ambient radioactivity conditions in the local and regional areas are described, including the combined effects of previous and existing developments (Base Case). The existing environment represents the historical and current environmental pressures that have shaped the observed patterns in the environment (i.e., natural variation), and provide a reference, from which to compare the effects of the NSDF Project to.
- **Step 3 – Evaluate Project interactions and mitigation** (refer to Section 5.7.5 Project Interactions and Mitigation). Project components and/or activities with the potential to change ecological health are identified and mitigation developed to limit or avoid effects are presented. A pathways analysis is then used to focus further assessment on key interactions between the NSDF Project and the environment by evaluating the different effect pathways to determine if, after incorporation of mitigation, there is still potential to cause residual effects to ecological health. Where effects are adequately mitigated and are not forwarded for further analysis (i.e., secondary pathways, or where mitigation will remove the pathway altogether), the reasons for concluding the assessment at this stage are articulated. Primary pathways that may lead to residual effects to ecological health after incorporating mitigation are carried forward to Step 4 for further analysis and residual effects characterization.
- **Step 4 – Present the methods and results of the residual effects analysis** (refer to Section 5.7.6 Residual Effects Analysis). This section summarizes the methods used to predict and characterize residual effects to ecological health from primary effect pathways. The results of the ecological risk assessment are presented including the characterization of residual incremental effects of the NSDF Project and the cumulative effects of the NSDF Project in combination in combination with other reasonably foreseeable developments (if applicable).

- **Step 5 – Describe the level of certainty and management of uncertainty** (refer to Section 5.7.7 Prediction Confidence and Uncertainty). Evaluate the available literature, data, and models used for the ecological health assessment, and describe the level of certainty that can be placed on predicted residual effects. This section will also identify how the uncertainty has been managed so that the effects are not underestimated.
- **Step 6 – Classify and determine the significance of the predicted residual effects** (refer to Section 5.7.8 Residual Effects Classification and Determination of Significance). Residual effects predicted from primary pathways are classified and a determination of the significance of the predicted residual effects of the NSDF Project on ecological health is made. Relative to other sections, the ecological health assessment uses a slightly different approach to the classification of residual effects and evaluation of significance, because several of the criteria (e.g., geographical extent, duration, frequency and reversibility) are already incorporated into the risk estimates and, therefore, are not independent variables.
- **Step 7 - Identify monitoring and follow-up** required to confirm effects predictions and address uncertainty (refer to Section 5.7.9 Monitoring and Follow-up).
- **Step 8 - Present a consolidated summary of conclusions** and outcomes of the assessment of residual effects on ecological health (refer to Section 5.7.10 Conclusions).

Information and concerns raised by the public, communities of interest, regulators, and First Nations and Métis communities during engagement that influenced the scope of the ecological health assessment are summarized in Table 5.7.1-1. Other general concerns and questions raised during the engagement that pertain to the ambient radioactivity and ecological health assessment (if any) are documented in Appendix 4.0-22 Public Feedback Received.

Table 5.7.1-1: Summary of Issues Raised During Engagement Activities that Influenced the Scope of the Ecological Health Assessment

Issue	How the Issue Was Included in the Assessment
Effects to fish from potential for contamination in the Ottawa River from the NSDF Project.	The spatial boundaries of the assessment were selected to include consideration of potential effects to the Ottawa River. The ecological risk assessment considered potential changes in surface water in Perch Creek and meeting guidelines within the Perch Creek basin is considered to be protective of fish in the Ottawa River.
Potential for radioactivity from gases from the capped facility	Potential changes in air quality from the NSDF Project were evaluated in the ecological health assessment during the operations phase.
Potential for changes in groundwater quality to affect uses downstream of the ECM	Potential changes in groundwater quality from the NSDF Project were evaluated in the ecological health assessment and included potential changes from treated effluent discharge from the wastewater treatment plant (WWTP), and seepage from the engineered containment mound (ECM) during the operations phase and Institutional Control period.
Treatment of leachate	Leachate from the ECM will be collected and pumped to the WWTP for treatment prior to discharging to the infiltration area.
Potential leakage of leachate from the ECM	Potential leakage of leachate from the ECM during operations will be mitigated through the design and implementation of a composite base liner system, a leachate detection system and a leak collection system. Potential leakage from the ECM during the operations phase and Institutional Control period is considered in the ecological health assessment.

5.7.2 Valued Components

Valued components refer to environmental features that may be affected by a project and that have been identified to be of concern by the proponent, scientists, government agencies, First Nation and Métis peoples, or the public (Canadian Environmental Assessment Agency 2014). A functioning ecosystem involves interactions of multiple species ranging in size and complexity from bacteria to apex wildlife predators. Each species is likely to respond differently to levels of substances present in environmental media. Because it is not possible to directly assess the risk for each individual species, it is necessary to simplify the complex ecosystem into organism groups and trophic linkages. To this end, the general ecology of the NSDF Project footprint was reviewed using existing information, and the species present were divided into major ecosystem components representing different potential health exposure pathways. Representative receptor taxa were then selected as surrogates for each ecosystem component and are listed in Table 5.7.2-1.

Representative receptor taxa were selected from those that are documented to occur or potentially occur in the local and regional study areas (see Section 5.7.3.1 Spatial Boundaries), have a relatively high potential for exposure to potentially impacted media, play a key role in the food web, and represent a variety of habits and trophic levels (CNL 2016a). A smaller group of indicator species was chosen to represent VCs selected for assessment. Indicator species were chosen based on at least one of the following criteria:

- they are reflective of the main exposure pathways, feeding habits, habitats, etc. on the site, and particularly those associated with the highest exposures;
- they are known to reside on the site, and therefore, are potentially exposed to environmental effects from the NSDF;
- represents a major plant or animal group;
- they are representative of their trophic level, resulting in representation for all trophic levels and therefore, all exposure pathways;
- they are particularly sensitive to stressors;
- they occupy a unique niche in the habitat or have a unique diet;
- they are ecologically significant (e.g., classified as Species at Risk); and,
- they have a special socio-economic importance or value (e.g., due to their economic value or cultural importance).

Table 5.7.2-1: Valued Components and Indicator Species for Ecological Health Assessment

Environmental Component	Taxa	Category	Valued Components		Effects (Habitat, Exposure)	Indicator Species	Justification for Inclusion in Exposure Assessment
			Population Group or Habitat Type	Species At Risk or Regional Rare Species			
Aquatic environment	Benthic Macroinvertebrate	Crustaceans	N/A	N/A	Exposure	Crayfish	Indicator species for changes in sediment quality
	Fish	Small Pelagic forage (omnivores)	Fish and Fish Habitat	■ Bluntnose Minnow ■ Common Shiner ■ Creek Chub ■ Pumpkinseed ■ Blacknose Shiner ■ Fathead Minnow ■ Pearl Dace	Habitat, Exposure	Bluntnose minnow	Present in Perch Creek, represents small pelagic fish
		Small - Benthivorous	Fish and Fish Habitat	■ Johnny Darter Brown Bullhead ■ Black Bullhead Longnose Dace	Habitat, Exposure	Black Bullhead	Present in Perch Creek, represents small benthivorous fish
		Large - Benthivorous	Fish and Fish Habitat	■ Lake Sturgeon ■ White Sucker	Habitat, Exposure	Not applicable[(a)]	Not present in the Local Study Area, where surface water concentrations are higher than in the Ottawa River
		Small - Carnivorous	Fish	■ Logperch ■ Fallfish ■ Yellow Perch ■ Mottled Sculpin	Habitat, Exposure	Not applicable[(a)]	Not present in the Local Study Area, where surface water concentrations are higher than in the Ottawa River
		Large - Carnivorous	Fish	Northern Pike	Habitat, Exposure	Northern Pike	Present in Perch Lake, represents Large Carnivorous fish

Table 5.7.2-1: Valued Components and Indicator Species for Ecological Health Assessment

Environmental Component	Taxa	Category	Valued Components: Population Group or Habitat Type	Valued Components: Species At Risk or Regional Rare Species	Effects (Habitat, Exposure)	Indicator Species	Justification for Inclusion in Exposure Assessment
Terrestrial Environment	Plant	Aquatic	Vegetation Communities	N/A	Exposure	Reed (food for predators)	Present in the wetlands in the Local Study Area, represents aquatic vegetation communities, foodchain
		Terrestrial	Vegetation Communities	N/A	Exposure	Red Maple	Present in the Local Study Area, represents terrestrial vegetation communities
	Insect	Pollinator	N/A	Monarch Butterfly	Exposure	Monarch Butterfly	Present in the Local Study Area, represents Pollinators
	Detritivore	Terrestrial Invertebrate	N/A	N/A	Exposure	Earthworm	Indicator species for changes in soil quality
	Mammal	Small - Insectivores	Bats	▪ Little brown Myotis ▪ Eastern small-footed Myotis ▪ Northern Myotis ▪ Tri-coloured Bat	Habitat, Exposure	Little brown Myotis	Present in the Local Study Area, represents small insectivores
		Small - Herbivore	N/A	N/A	Exposure	Meadow Vole	Present in the Local Study Area, represents small herbivorous mammals
		Large - Herbivore	N/A	N/A	Exposure	White-tailed deer[(b)]	Present in the Local Study Area, represents large herbivorous mammals, public interest
		Small - Omnivorous	N/A	N/A	Exposure	Short-tailed Shrew	Present in the Local Study Area, represents small omnivorous mammals

Table 5.7.2-1: Valued Components and Indicator Species for Ecological Health Assessment

Environmental Component	Taxa	Category	Valued Components		Effects (Habitat, Exposure)	Indicator Species	Justification for Inclusion in Exposure Assessment
			Population Group or Habitat Type	Species At Risk or Regional Rare Species			
Terrestrial Environment (continued)	Mammals (continued)	Large - Omnivorous	N/A	N/A	Exposure	Black Bear[(b)]	Present in the Local Study Area, represents large omnivorous mammals, public interest
		Large - Carnivorous	N/A	Eastern Wolf	Exposure	Eastern Wolf[(b)]	Present in the Local Study Area, represents large carnivorous mammals, public interest
	Reptile	Semi-terrestrial	Turtle	■ Blanding's Turtle ■ Snapping Turtle	Habitat, Exposure	Snapping Turtle[(c)]	Present in the Local Study Area, represents semi-terrestrial reptiles (turtle)
		Semi-terrestrial	Snake	N/A	Exposure	Common Watersnake	Present in the Local Study Area, represents semi-terrestrial reptiles (snake)
		Terrestrial	Snake	N/A	Exposure	Eastern Milksnake	Present in the Local Study Area, represents terrestrial reptiles (snake)
	Amphibian	Semi-aquatic	Frog	N/A	Exposure	Green Frog	Present in the wetlands in the Local Study Area, represents semi-aquatic amphibians

Table 5.7.2-1: Valued Components and Indicator Species for Ecological Health Assessment

Environmental Component	Taxa	Category	Valued Components		Effects (Habitat, Exposure)	Indicator Species	Justification for Inclusion in Exposure Assessment
			Population Group or Habitat Type	Species At Risk or Regional Rare Species			
Terrestrial Environment (continued)	Bird	Small – Insectivores	Migratory birds	■ Wood Thrush ■ Veery ■ Eastern Wood-pewee ■ Black-throated Blue Warbler ■ Least Flycatcher ■ Chestnut-sided Warbler ■ Common Yellowthroat ■ Mourning Warbler ■ Brown Thrasher ■ Golden-winged Warbler ■ Canada Warbler	Habitat, Exposure	Canada Warbler	Present in the Local Study Area, represents small insectivores birds
		Large Insectivores	Migratory birds	■ Eastern Whip-poor-will ■ Yellow-bellied Sapsucker	Habitat, Exposure	Eastern Whip-poor-will	Present in the Local Study Area, represents large insectivore birds
		Small Omnivores	Migratory birds	■ Purple Finch ■ Rose-breasted Grosbeak ■ White-throated Sparrow	Exposure	Purple Finch	Present in the Local Study Area, represents small omnivore birds

Table 5.7.2-1: Valued Components and Indicator Species for Ecological Health Assessment

Environmental Component	Taxa	Category	Valued Components		Effects (Habitat, Exposure)	Indicator Species	Justification for Inclusion in Exposure Assessment
			Population Group or Habitat Type	Species At Risk or Regional Rare Species			
Terrestrial Environment (continued)	Bird (continued)	Large Omnivores	N/A	■ Northern Flicker ■ Ruffed Grouse	Exposure	Ruffed Grouse	Present in the Local Study Area, represents large omnivore birds
		Small Carnivores	N/A	Belted Kingfisher	Exposure	Belted Kingfisher	Present in the Local Study Area, represents small carnivore birds
		Large Carnivores	Raptors	Bald Eagle	Exposure	Bald Eagle	Present in the Local Study Area, represents large carnivore birds, public interest
		Small semi-aquatic	Waterfowl	■ American blackduck ■ Mallard	Exposure	Mallard	Present in the Local Study Area, represents small semi-aquatic birds, public interest
		Large semi-aquatic	N/A	Great Blue Heron	Exposure	Great Blue Heron	Present in the Local Study Area, represents large semi-aquatic birds, public interest

a) These species are not selected as they don't represent the bounding case from dose assessment perspective.
b) These species were not selected on basis of their large home range
c) Snapping turtle is selected as the surrogate for Blanding turtle for exposure.

Assessment endpoints are qualitative expressions used to assess the significance of residual effects on VCs and represent the key properties of the VC that should be protected for future human generations (i.e., incorporates sustainability). The assessment endpoint is the protection of ecological health. Measurement endpoints represent properties of the environment, that when changed, could result in or contribute to an effect on an assessment endpoint. The measurement endpoints for the ecological health assessment are outlined in Table 5.7.2-2.

Table 5.7.2-2: Assessment Endpoint and Measurement Indicators for the Ecological Health Assessment

Valued Component	Assessment Endpoint	Measurement Indicators
Indicator species listed in Table 5.7.2-1	Protection of ecological health	■ Changes to air quality ■ Changes to groundwater quality ■ Changes to sediment quality ■ Changes to surface water quality ■ Changes to soil quality ■ Changes to vegetation quality

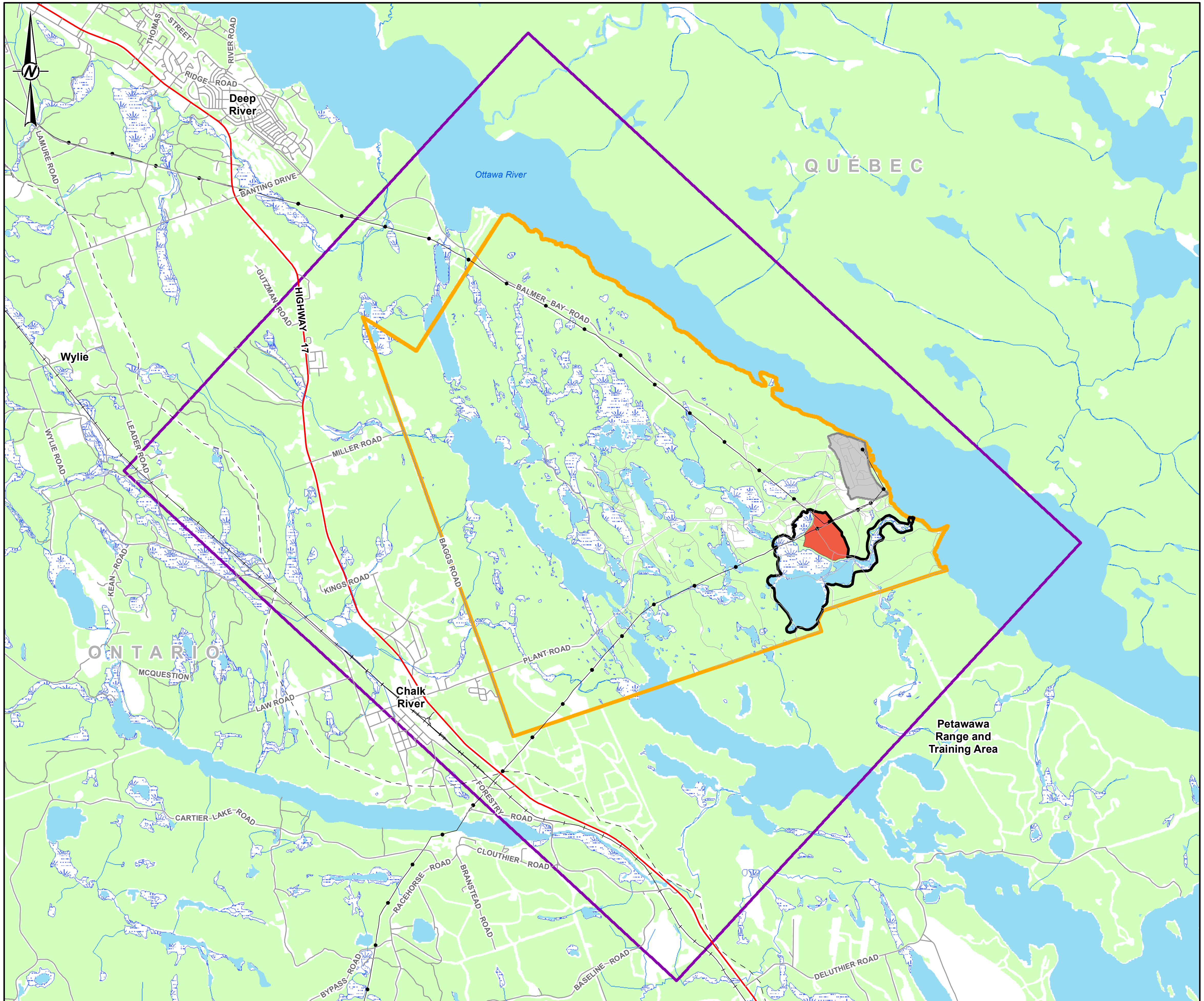
5.7.3 Assessment Boundaries

5.7.3.1 Spatial Boundaries

The spatial boundaries for ecological health were thus selected to incorporate relevant portions of the study areas for air quality, groundwater quality and surface water quality to evaluate the environmental changes that could contribute to effects on ecological health. The spatial boundaries for the characterization of ambient radioactivity and subsequent effects assessment are as follows (Figure 5.7.3-1):

- **Site Study Area (SSA):** The SSA is the NSDF Project footprint (i.e., where Project activities would be undertaken including the NSDF Project's proposed facilities, buildings and infrastructure).
- **Local Study Area (LSA):** The LSA is defined as the area within which there is potential for measurable changes to measurement indicators resulting from the proposed NSDF Project activities. The LSA adapted from the groundwater and surface water Regional Study Area (RSA) and is designated as the spatial extent of the Perch Creek watershed, and includes Perch Lake and its tributaries, and Perch Creek. The Ottawa River in the vicinity of the mouth of Perch Creek is also included in the LSA.
- **Regional Study Area (RSA):** The RSA is defined as the area within which the potential effects of the NSDF Project may interact with the effects of other existing or reasonably foreseeable projects. Non-human biota in the vicinity of the engineered containment mound (ECM) could be exposed to airborne and waterborne emissions as well as direct gamma radiation from the waste. Residual contaminants from the Waste Water Treatment Plant (WWTP) effluent will be most concentrated with the East Swamp Stream due to dilution in Perch Lake, Perch Creek and the Ottawa River. Doses to non-human biota exposed to the aquatic habitat of East Swamp Stream were calculated to provide a bounding estimate of potential exposure. Therefore, the RSA was adapted from the air quality study area as this is the largest extent of potential cumulative effects on ecological health; the air quality RSA is defined as an approximate 10 kilometre (km) by 10 km rectangle surrounding the LSA, and oriented parallel to the Ottawa River.

This page left intentionally blank



LEGEND

- HIGHWAY
- ROAD
- RAILWAY
- TRANSMISSION LINE
- NATURAL GAS PIPELINE
- RIVER/STREAM
- WATERBODY
- WETLAND
- WOODED AREA
- SITE STUDY AREA (NSDF PROJECT SITE)
- CRL MAIN CAMPUS
- CRL PROPERTY
- LOCAL STUDY AREA
- REGIONAL STUDY AREA

2.5 0 2.5

1:60,000 KILOMETRES

REFERENCE(S)

1. BASEMAP:SOURCES: ESRI, HERE, DELORME, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), SWISSTOPO, MAPMYINDIA, © OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
2. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
3. HIGHWAYS AND FIRST NATION RESERVES MNRF 2016
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE18N

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
ECOLOGICAL HEALTH STUDY AREAS

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	EM
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0001	0.0	5.7.3 1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm

This page left intentionally blank

5.7.3.2 Temporal Boundaries

Temporal boundaries (i.e., project phases) establish the timeframe during which NSDF Project effects are assessed. The temporal boundary represents the timeframe during which project activities are actively occurring, and considers the duration of predicted residual effects. The duration of an effect is defined as the amount of time between the start and end of a Project activity or stressor (which is related to the project phases) plus the time required for the residual effect to be reversed. In some cases, a residual effect may be irreversible within the temporal boundaries of the Project or if the effects were predicted to last so far into the future that they could not be predicted with any level of certainty (e.g., residual effect lasts for thousands of years). The following phases were identified for the NSDF Project:

- **Construction Phase**: includes site preparation and all activities associated with the construction of the NSDF. This phase includes activities such as installing the necessary supporting and/or ancillary facilities and NSDF infrastructure to facilitate NSDF operations, inactive commissioning and systems testing, and transportation of construction materials. Construction activities are expected take place from 2018 to 2020.
- **Operations Phase**: includes all activities associated with the landfilling of waste receipt, waste placement, water management, wastewater treatment plant operations, vehicle movements into and from the NSDF Project site, and maintenance activities. Operations activities are expected to last approximately 50 years (i.e., 2020 to 2070).
- **Closure Phase:** includes activities necessary to complete the installation of the final cover and implementation of long-term monitoring. Closure activities are expected to start in 2070 and continue through to 2100, after which the NSDF Project will transfer into the post-closure phase.
- **Post-closure Phase:** has two discrete periods: Institutional Control and post-Institutional Control. The Institutional Control period includes implementation of both active and passive control throughout 2100 to 2400 (i.e., 300 years). During Institutional Control, groundwater monitoring and groundwater quality management will continue to demonstrate compliance with the safety case assumptions. Post-institutional Control occurs after year 2400 and continues indefinitely.

The temporal boundaries for the ecological health assessment include consideration of effects of the NSDF Project during the operations phase, and the post-Institutional Control period of the post-closure phase.

5.7.3.3 Assessment Cases

The assessment cases considered in the ambient radioactivity assessment include the Base Case and Application Case:

- **Base Case –** This scenario represents existing conditions and characterizes combined effects from previous and existing developments and activities. The Base Case reflects the effects of existing disturbances, such as forestry, transportation, agricultural, mining, and residential and recreational development. Current effects from the existing CRL facilities and operations, for example, are considered part of the Base Case.
- **Application Case –** This scenario represents predictions of the effects of the Base Case combined with the effects that may result from the NSDF Project. The Application Case considers potential effects from the NSDF Project during the operations phase and the Institutional Control period.

- **Reasonably Foreseeable Developments (RFD) Case** – This scenario represents predictions of the cumulative effects of the Application Case, which includes the Base Case, plus projects that are currently under application review or that have officially entered a regulatory application process, and are therefore, considered reasonably foreseeable. There are no RFDs expected in the CRL property (i.e., the RSA) with the exception of new/upgrades to research and development facilities, new support infrastructure, and ongoing decommissioning and environmental restoration activities. Potential effects from these activities are not expected to spatially overlap with potential effects to ecological health from the NSDF Project. The NSDF Project will enable the remediation of contaminated lands and legacy waste management areas, and decommissioning of outdated infrastructure at the CRL property and CNL's other business locations to support future CNL missions. The end-state plan for the CRL site will be to return lands disturbed by site activities to a condition that is physically stable, and safe in keeping with the land use and landscape of the day. Therefore, decommissioning and environmental restoration activities are anticipated to positively affect ecological health. Because RFDs will either have no spatial overlap or are likely to positively affect ecological health, an RFD Case is not presented as part of this assessment.

5.7.4 Description of the Environment

Effluent and environmental monitoring data from CRL and the surrounding area are used to establish a baseline characterization of ambient radioactivity in environmental media. The current CRL radiological effluents are described and the environmental concentrations of radiological contaminants are described for each environmental medium that could potentially be affected by the operations of the NSDF Project. Where possible, five-year datasets (e.g., from 2011 to 2015) are provided.

5.7.4.1 Background Sources of Radiation and Radioactivity

This section describes the background radiation and radioactivity that is present in the environment due to natural and anthropogenic sources independent of CRL operations. The magnitude of radiation dose from natural sources varies greatly, both spatially and temporally. The main natural sources of radiation are cosmic rays; naturally-occurring radionuclides in air, water, and food; and naturally-occurring radionuclides in the soil, rocks and building materials used in homes (CNSC 2013).

Cosmic radiation originates from celestial events and the sun. This cosmic radiation and the secondary particles produced penetrate the Earth's atmosphere and give an external radiation dose at the Earth's surface. Naturally occurring radionuclides such as uranium, potassium, and thorium are present in soils, rocks and building materials. These naturally-occurring radionuclides also contribute to the external gamma radiation dose.

Naturally occurring radionuclides also incorporate into plants, animals, and water from surrounding soils and rocks. Humans ingest these foodstuffs and receive an internal radiation dose. Radon gas, a product of the decay of uranium in soil, is inhaled and also contributes to the internal radiation dose. The average annual doses in Canada are shown on Figure 5.7.4-1; the total annual dose is about 1.8 millisieverts (mSv) (Grasty and LaMarre 2004).

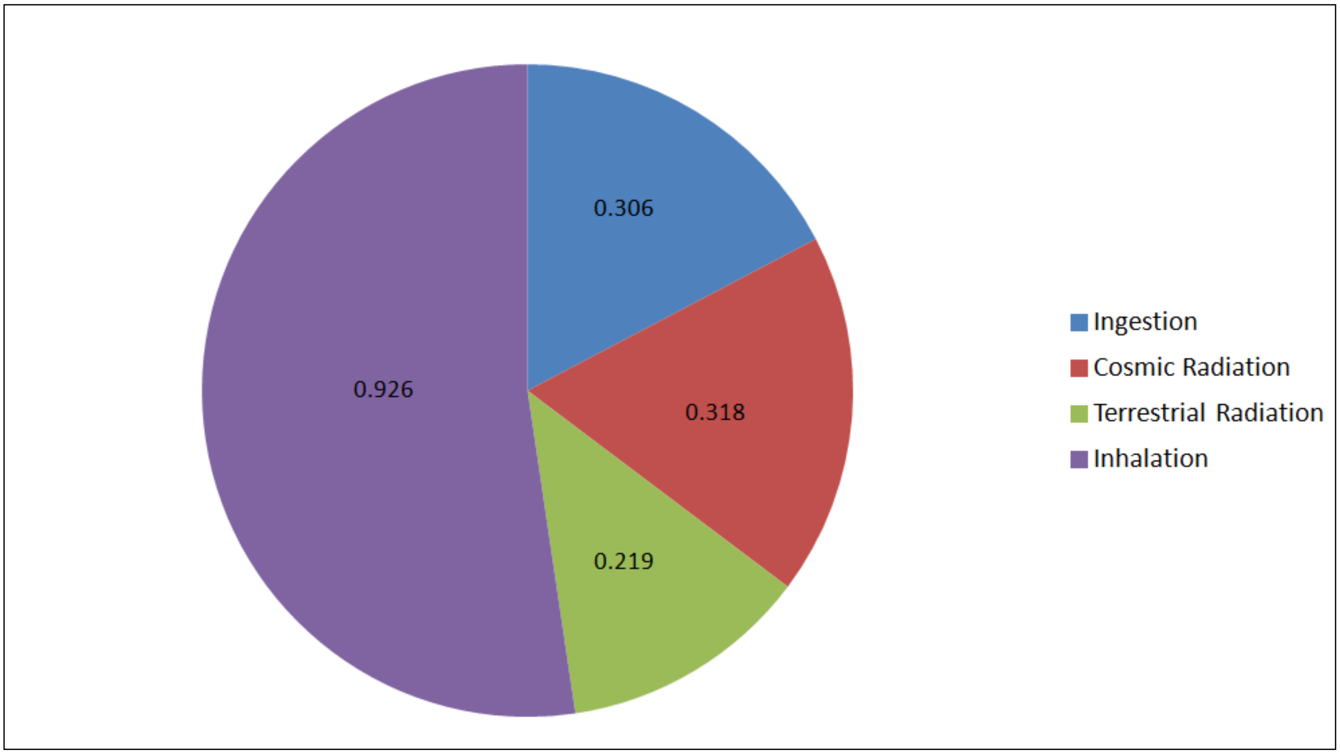


Figure 5.7.4-1: Average Background Radiation Doses in Canada (mSv/y) (Grasty and LaMarre 2004)

Some radionuclides released from CRL are already present in environmental media due to natural and anthropogenic sources, such as atmospheric fallout from global weapons testing. Where applicable, environmental concentrations are compared to expected background levels or measurements of samples from reference areas outside the RSA, in order to distinguish the impact of CRL operations from radiological contamination which is present due to other sources.

5.7.4.2 Radioactive Releases from Chalk River Laboratories

This section summarizes the radioactive releases from CRL operations to the environment, including airborne and liquid effluents. The airborne radiological effluent verification monitoring program includes continuous monitoring of Argon-41 (Ar-41), mixed fission product noble gases, Carbon-14 (C-14), tritium oxide, elemental tritium, Iodine-125 (I-125), Iodine-131 (I-131), gross alpha particulates, and gross beta particulates, from applicable operational facilities on the CRL property.

In 2015, the major sources of airborne radiological effluent from CRL operations were (CNL 2016b):

- the B109 stack that exhausts ventilation and cooling air from the National Research Universal (NRU) reactor;
- the B206 Stack that exhausts the Molybdenum Production Facility and Cell 1 of the Universal Cells;
- emissions from the cemented molybdenum waste storage; and,
- secondary roof vents and fugitive emissions exhausting various rooms within NRU.

It is noted that emissions from the B206 stack and cemented molybdenum waste storage are no longer significant as the facility has been shut down (production ceased in 2016).

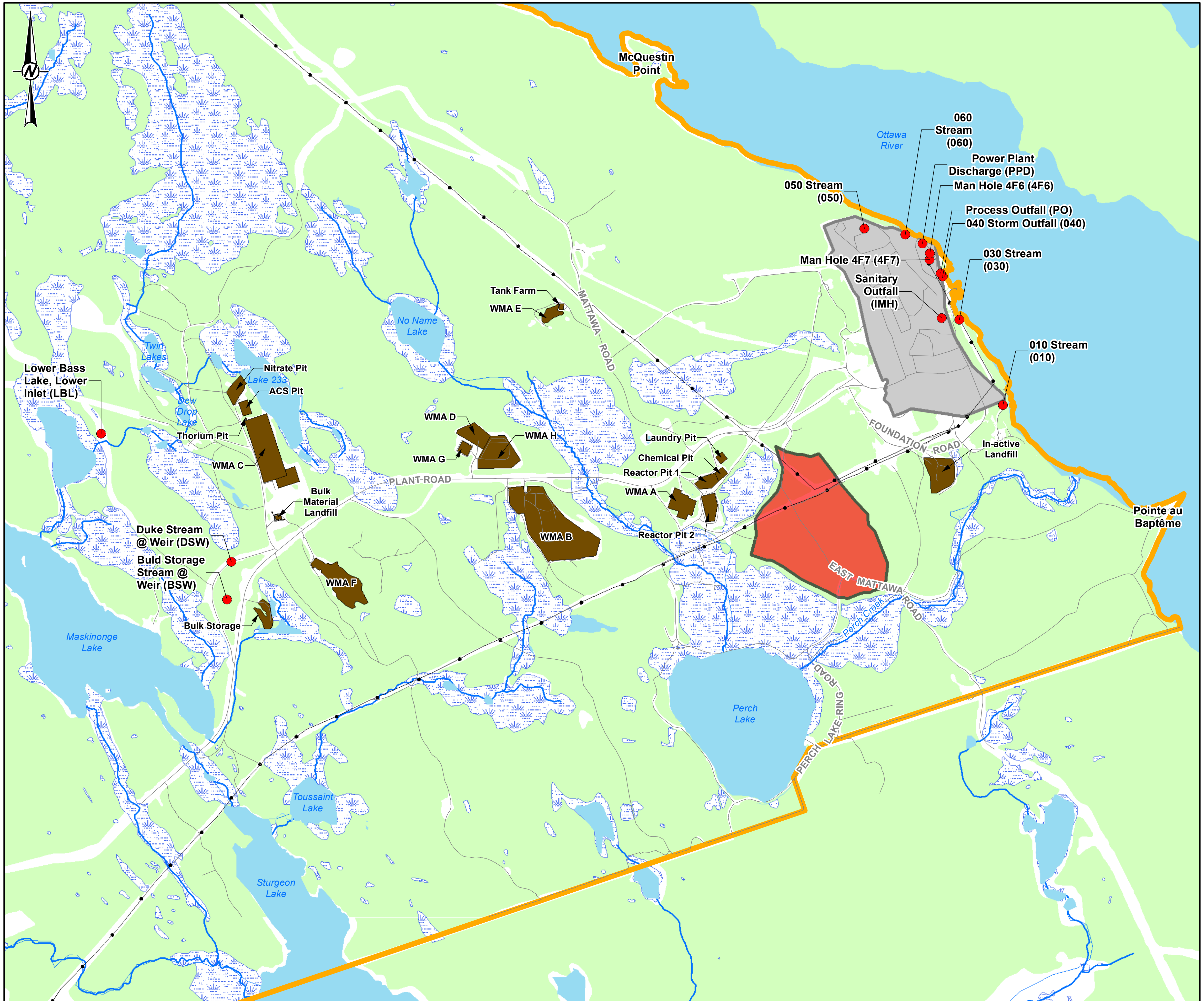
The liquid radiological effluent verification monitoring program includes 13 monitoring points, in addition to upstream monitoring points used for reference. These locations are routinely monitored for gross alpha particulates, gross beta particulates, and tritium oxide. Depending on the monitoring location, liquid effluent monitoring is performed at these locations using automatic samplers, weekly or monthly grab samples, or composite sampling. Tritium, gross alpha, and gross beta are analyzed at least monthly for all monitoring locations, and weekly for the Process Sewer and Sanitary Outfall. Gamma spectroscopy is performed on liquid effluent samples at a frequency ranging from weekly to annually or as needed, depending on the effluent stream. CRL's radiological liquid effluent monitoring locations are shown on Figure 5.7.4-2. The environmental monitoring locations are discussed further down in this section.

The major sources of liquid radiological effluent at CRL property and the associated monitoring locations are as follows (CNL 2016b):

- the NRU reactor, Waste Treatment Centre, and active laundry facility (monitored at the Process Outfall);
- contaminated groundwater discharge from the waste management areas (WMAs) (monitored at on-site surface waters); and,
- groundwater discharges to the Ottawa River from sources inside the Controlled Area (monitored with on-site groundwater wells).

Leachate from WMA A and the Liquid Dispersal Area (LDA) may be particularly relevant due to their proximity to the NSDF site. These are sources of Strontium-90 (Sr-90) and tritium, which are monitored as part of the Environmental Monitoring Program, and are monitored downstream at the Perch Creek Weir effluent monitoring location. Monitoring includes monitoring downgradient of the Waste Management Areas and surface water bodies in various locations.

The annual sum of airborne and liquid effluent releases from 2011 to 2015 is presented in Table 5.7.4-1. Derived Release Limits (DRL) have been developed for the CRL property based on Canadian Standard Association (CSA) Standard N288.1-14. They are calculated limits for airborne and liquid releases of radionuclides such that the highest radiation dose to a member of the public does not exceed 1 mSv. While DRLs are relevant to the dose received by off-site human receptors, they are provided in this section only for context regarding the magnitude of releases. The major radiological contaminants in terms of percentage of DRL are Ar-41 (5.9 percent [%] of DRL in 2015), I-131 (0.8% of DRL in 2015), Mixed Fission Product Noble Gases (0.7% of DRL in 2015), and airborne tritium oxide (0.7% of DRL in 2015).



LEGEND

- ROADS
- RAILWAY
- TRANSMISSION LINE
- RIVER/STREAM
- WATERBODY
- WETLAND
- WOODED AREA
- SITE STUDY AREA (NSDF PROJECT SITE)
- CRL MAIN CAMPUS
- CRL PROPERTY
- WASTE MANAGEMENT AREA (WMA) [1]
- LIQUID EFFLUENT MONITORING LOCATION

500 0 500

1:20,000 METRES

NOTE(S)

1. LIQUID DISPOSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.

REFERENCE(S)

1. BASEDATA ONTARIO MNRF 2016, CANVEC 2016, AND CNL 2016
2. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
3. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE18N

CLIENT

CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT

NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE

RADIOLOGICAL LIQUID EFFLUENT MONITORING LOCATIONS AT CHALK RIVER LABORATORIES

CONSULTANT

Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	MM
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.7.4-2

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:

This page left intentionally blank

Table 5.7.4-1: Chalk River Laboratories Annual Effluent Releases from 2011 to 2015

	Release Limit	2011	2012	2013	2014	2015	2011-2015 Average
Airborne Releases							
Argon-41 (Bq/yr)	$6.60{\times}10^{16}$	$1.09{\times}10^{16}$	$9.33{\times}10^{15}$	$8.46{\times}10^{15}$	$9.37{\times}10^{15}$	$1.29{\times}10^{16}$	$1.02{\times}10^{16}$
Carbon-14 (Bq/yr)	$2.14{\times}10^{15}$	$5.56{\times}10^{11}$	$6.41{\times}10^{11}$	$5.74{\times}10^{11}$	$8.69{\times}10^{11}$	$3.77{\times}10^{11}$	$6.03{\times}10^{11}$
Tritium Oxide (Bq/yr)	$1.25{\times}10^{16}$	$9.72{\times}10^{13}$	$2.45{\times}10^{14}$	$2.46{\times}10^{14}$	$2.60{\times}10^{14}$	$2.77{\times}10^{14}$	$2.25{\times}10^{14}$
Iodine-131 (Bq/yr)	$3.96{\times}10^{12}$	$3.73{\times}10^{9}$	$3.19{\times}10^{10}$	$1.38{\times}10^{11}$	$2.06{\times}10^{11}$	$1.03{\times}10^{11}$	$9.65{\times}10^{10}$
Mixed Fission Product Noble Gases (BqMeV/yr)	$4.96{\times}10^{16}$	$9.36{\times}10^{14}$	$8.80{\times}10^{14}$	$1.32{\times}10^{15}$	$2.11{\times}10^{15}$	$1.20{\times}10^{15}$	$1.29{\times}10^{15}$
Xenon-133 (Bq/yr)	$8.35{\times}10^{17}$	$5.93{\times}10^{15}$	$5.04{\times}10^{15}$	$5.72{\times}10^{15}$	$8.85{\times}10^{15}$	$4.89{\times}10^{15}$	$6.09{\times}10^{15}$
Liquid Releases							
Tritium Oxide (Bq/yr)	$1.03{\times}10^{17}$	$3.16{\times}10^{12}$	$2.68{\times}10^{12}$	$2.43{\times}10^{12}$	$2.56{\times}10^{12}$	$3.29{\times}10^{12}$	$2.82{\times}10^{12}$
Gross Alpha (Bq/yr)	$1.32{\times}10^{12}$	$6.04{\times}10^{7}$	$4.23{\times}10^{7}$	$4.68{\times}10^{7}$	$7.56{\times}10^{07}$	$5.79{\times}10^{7}$	$5.66{\times}10^{7}$
Gross Beta (Bq/yr)	$2.70{\times}10^{13}$	$2.67{\times}10^{9}$	$2.32{\times}10^{9}$	$3.02{\times}10^{9}$	$2.18{\times}10^{10}$	$3.31{\times}10^{9}$	$6.62{\times}10^{9}$

Source: CNL 2016b

Note: The release limits listed above are 0.3 of the Derived Release Limits to account for the CRL site dose constraint of 0.3 mSv/y to the most exposed critical group

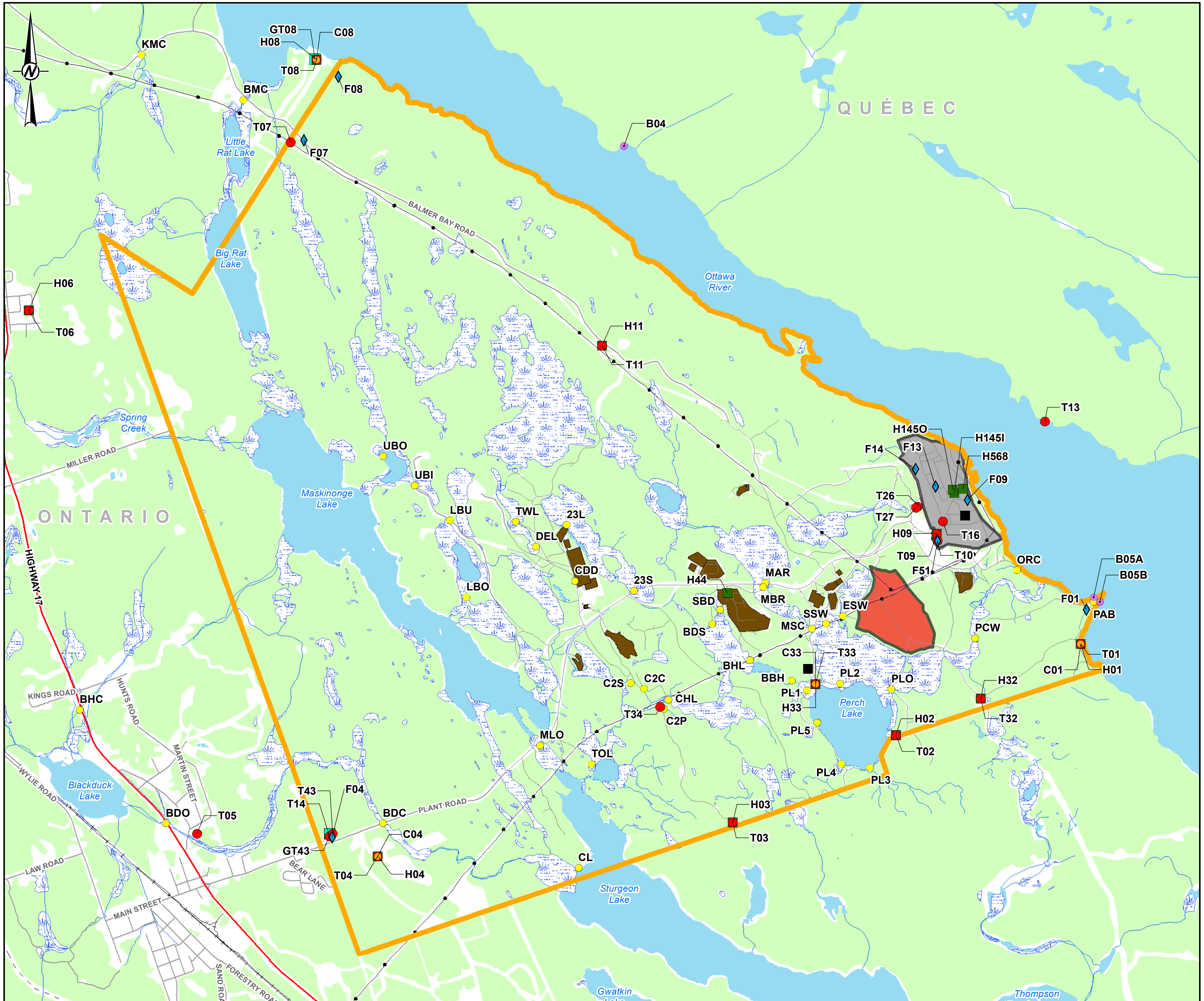
Bq/yr = Becquerels per year; BqMeV/yr = Becquerels-mega-electron volts per year.

5.7.4.3 Environmental Monitoring Program

This section describes the environmental monitoring program within and outside of the CRL property boundary. The environmental monitoring program is the source of the baseline radioactivity characterization data described in subsequent sections. The characterization of baseline radioactivity utilizes a 5-year data set from 2011-2015; this is considered to be the most accurate data set in terms of representing the background radioactivity at CRL prior to NSDF operations. It is noted that additional future site activities may impact the baseline radioactivity prior to NSDF operations. For example, the shutdown of NRU scheduled for 2018 will reduce airborne emissions at CRL and is expected to result in lower environmental concentrations of some radiological contaminants.

The CRL Environmental Monitoring Program (EMP) includes sampling and analysis of surface water, groundwater, sediment, soil, vegetation, ambient air, milk, garden produce, game animals, farm animals, and fish. Environmental monitoring of radiation in air includes continuous monitoring stations for ambient gamma, noble gases, C-14, and tritium. Results are reported in the annual CRL Environmental Monitoring Report. Monitoring of soil and vegetation on the CRL site has been performed through supplementary studies, including plume update studies and wetland contamination surveys conducted through the CRL groundwater monitoring program.

Monitoring locations are displayed for the on-site portion of the EMP on Figure 5.7.4-3. Off-site monitoring locations for radioactive air monitoring and radioactive liquid/biological monitoring are shown on Figure 5.7.4-4 and Figure 5.7.4-5, respectively. A summary of the radiological EMP monitoring parameters is shown in Table 5.7.4-2 and are described in more detail in the following sections.



LEGEND

- HIGHWAY
- ROAD
- RAILWAY
- TRANSMISSION LINE
- NATURAL GAS PIPELINE
- RIVER/STREAM
- WATERBODY
- WETLAND
- SITE STUDY AREA (NSDF PROJECT SITE)
- CRL MAIN CAMPUS
- WASTE MANAGEMENT AREA (WMA)[1]
- CRL PROPERTY
- BEACH SEDIMENT SAMPLE
- C-14 AIR
- THERMOLUMINESCENT DOSIMETER
- SURFACE WATER SAMPLE
- WET AND DRY DEPOSITION
- TRITIUM - AIR
- GAMMA TRACER
- METEOROLOGIC TOWER

NOTE(S)
1. LIQUID DISPOSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.

REFERENCE(S)
1. BASEDATA ONTARIO MNRF 2016, CANVEC 2016, AND CNL 2016
2. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
3. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE18N

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

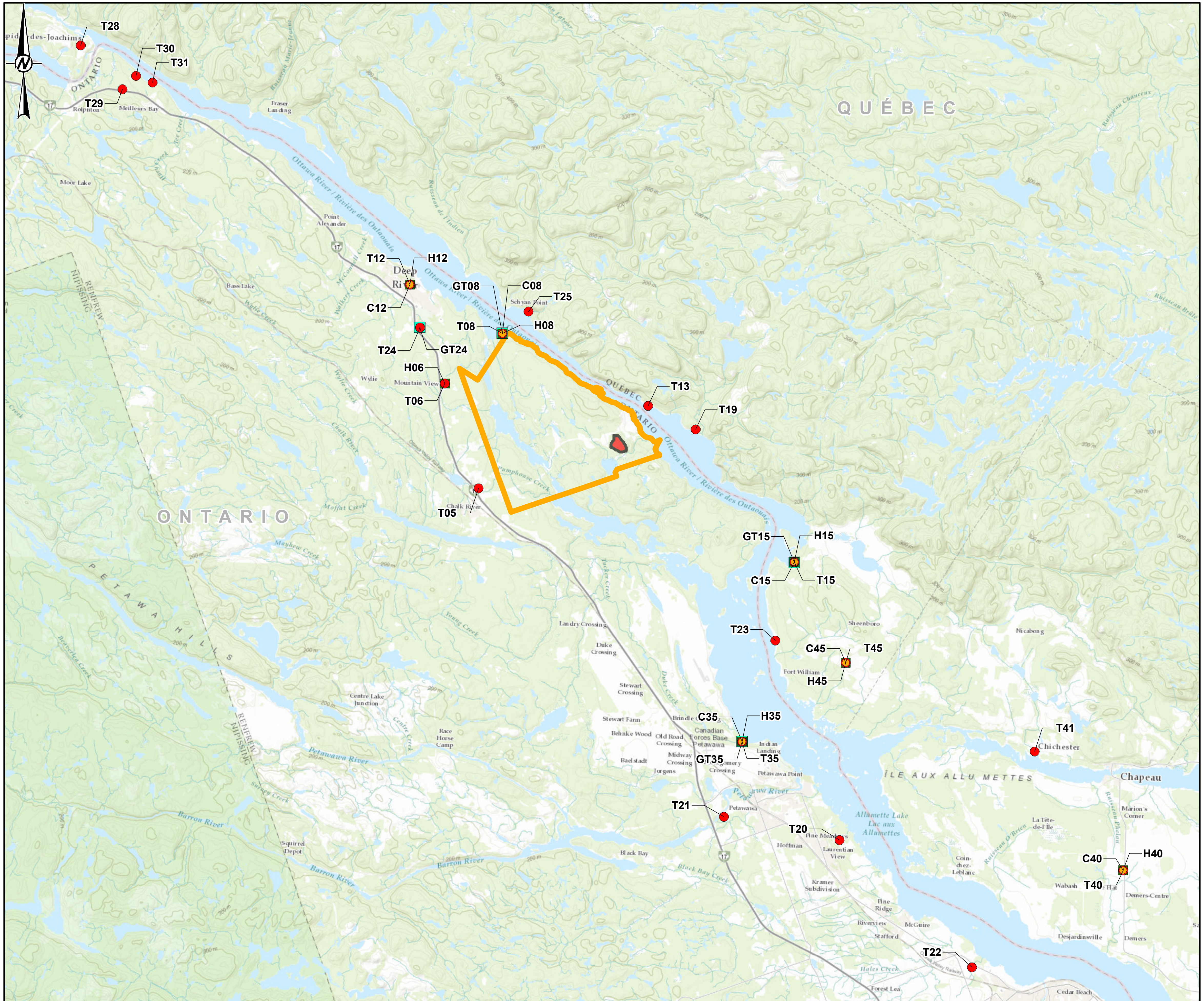
TITLE
RADIOLOGICAL ENVIRONMENTAL MONITORING LOCATIONS WITHIN THE CHALK RIVER LABORATORIES PROPERTY

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	MM
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.7.4-3

This page left intentionally blank



LEGEND

- NSDF PROJECT SITE
- CRL PROPERTY
- C-14 AIR
- THERMOLUMINESCENT DOSIMETER
- TRITIUM - AIR
- GAMMA TRACER

5 0 5

1:175,000 KILOMETERS

REFERENCE(S)

1. BASEMAP: SOURCES: ESRI, HERE, DELORME, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), SWISSTOPO, MAPMYINDIA, © OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
2. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
3. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE18N

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
OFF SITE RADIOACTIVE AIR QUALITY MONITORING LOCATIONS

CONSULTANT

Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	MM
APPROVED	AB

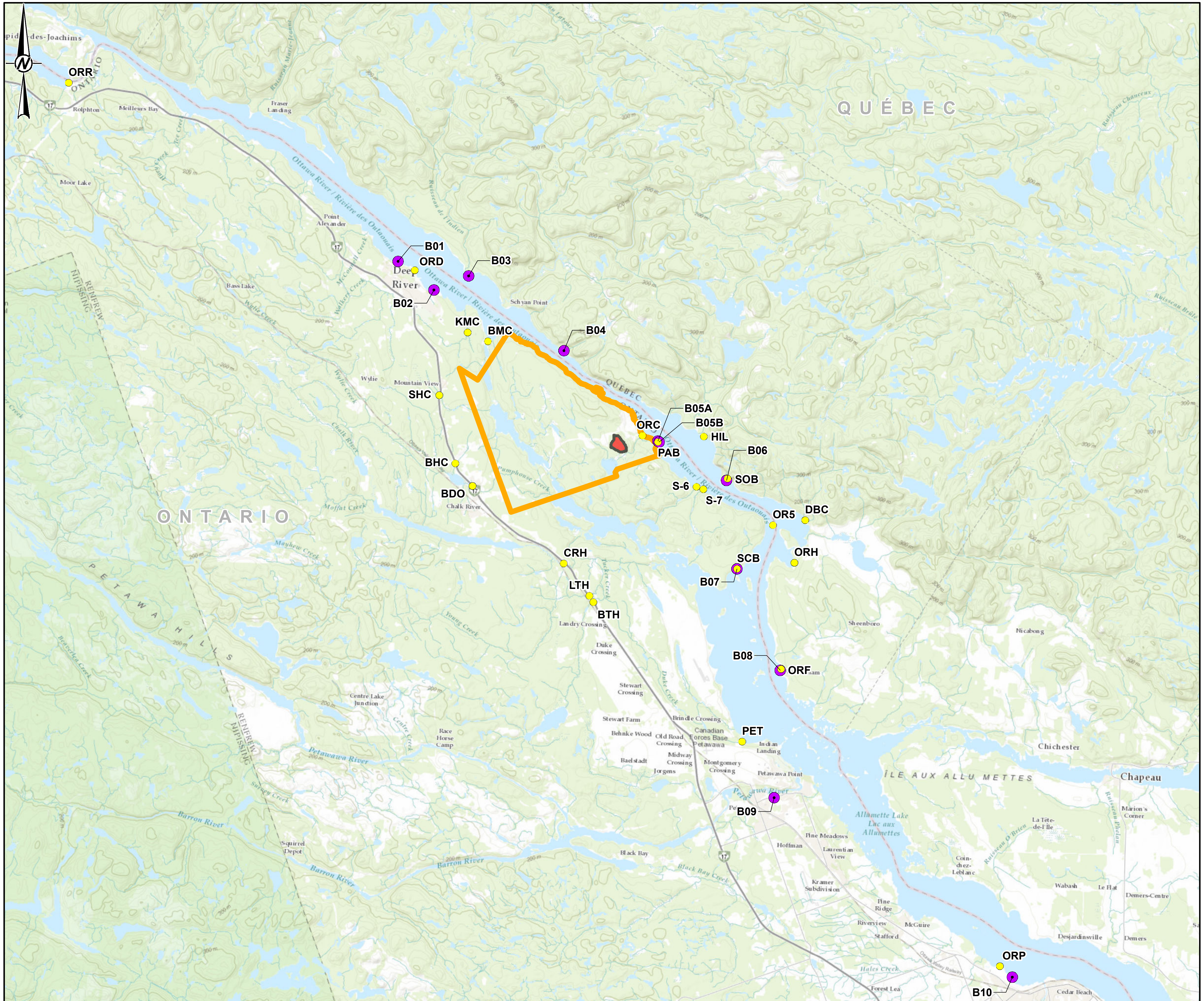
PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.7.4-4

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:

25mm

S:\Clients\Canadian_Nuclear_Laboratories\NSDF\99_PROJ\1547525_NSDF_EIS\40_PROD\0009_EIS_Section_5\Section_5_7_Ambient_Radioactivity\1547525-0009-G-0004.mxd

This page left intentionally blank



LEGEND

- NSDF PROJECT SITE
- CRL PROPERTY
- BEACH SEDIMENT SAMPLE
- SURFACE WATER SAMPLE

5 0 5

1:175,000 KILOMETERS

REFERENCE(S)

1. BASEMAP: SOURCES: ESRI, HERE, DELORME, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), SWISSTOPO, MAPMYINDIA, © OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
2. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
3. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE18N

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
OFF SITE RADIOACTIVE LIQUID AND BIOLOGICAL MONITORING LOCATIONS

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	MM
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.7.4-5

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm

This page left intentionally blank

Table 5.7.4-2: Summary of Chalk River Laboratories' Environmental Monitoring Program

Environmental Medium	Analysis	Sample Locations	Frequency
External Gamma	Ambient Gamma Dose (TLD)	23 monitoring stations on and off-site	Continuous sampling, analyzed quarterly and annually
Air	Noble Gas Dose (GammaTRACER radiation detector)	5 locations on and off-site	Continuous
Air	Ambient Tritium	14 locations on and off-site	Continuous sampling, quarterly analysis
Air	Ambient C-14	8 locations on and off-site	Continuous
Surface Water	■ Gross Alpha ■ Gross Beta ■ Tritium ■ Gamma Spectroscopy ■ Total Strontium	47 locations on and off-site	Daily to annually
Groundwater	■ Gross Alpha ■ Gross Beta ■ Tritium ■ C-14 ■ Gamma spec	180 on-site monitoring wells	Annual or semi-annual (Spring and Fall)
Soil and Vegetation	■ Gross Alpha ■ Gross Beta ■ Gamma Spectroscopy	Supplementary study locations on Chalk River Laboratories (CRL) property (plume updates, investigations)	Supplementary studies on 5 or 10 year frequency or as required
Beach Sand	Gamma Spectroscopy	8 public beaches along Ottawa river	Annual
Fish	■ Gross Alpha ■ Gross Beta ■ Gamma Spectroscopy	Three locations in Ottawa River, One lake on CRL property	Annual
Terrestrial Animals	■ Gross Alpha ■ Gross Beta ■ Gamma Spectroscopy ■ Tritium ■ Organically Bound Tritium	■ Game animals within 25 km of CRL ■ Beef samples from two off-site farms	Annual
Terrestrial Plants	■ Gross Alpha ■ Gross Beta ■ Gamma Spectroscopy ■ Free Water Tritium	Five private gardens and one farmers market off-site	Annual, during growing season
Milk	■ Tritium ■ Carbon-14 ■ Iodine-131 ■ Gamma Spectroscopy	One local dairy in Pembroke	■ Monthly analysis (I-131) ■ Quarterly analysis of weekly samples (Tritium, C-14, Gamma Spectroscopy)

Source: (CNL 2016c).

5.7.4.4 Radioactivity in the Atmospheric Environment

Airborne radiological contaminants are monitored as part of the CRL Environmental Monitoring Program. This includes measurements of ambient gamma dose, noble gas dose, tritium in air and C-14 in air. Monitoring is undertaken on the CRL main campus, at the property boundary, and at relevant off-site locations.

5.7.4.4.1 Ambient Gamma Dose

Ambient gamma dose measurements performed using Thermoluminescent Dosimeters (TLDs) yield total annual dose, including dose imparted by natural background sources as well as dose associated with releases from CRL operations. All TLD measurements have been corrected for exposure during storage, handling, and transport by subtracting the exposure received by control TLDs. These control TLDs are housed during the measurement period within lead shielding in a specifically constructed building at CRL, where background radiation from subsoil, radon, and building materials is very low. Consequently, the reported TLD results do not include exposure from high-energy cosmic radiation that penetrates the low background building and lead shielding in which the control TLDs are stored. The locations of all TLDs are shown in Section 5.7.4.3 Environmental Monitoring Program.

The TLD results are compared to the expected terrestrial gamma radiation dose in Ottawa, which occurs as a result of naturally-occurring radionuclides in the earth, air, and building materials. The outdoor external radiation dose rate in locations throughout Canada has been characterized based on TLD measurements at Canadian Environmental Stations from 1976 to 1984 (NCRP 1987). The closest monitoring location utilized in this study is Ottawa, approximately 185 km southeast of the CRL site. After subtracting the contribution of cosmic radiation, the average external gamma radiation dose from terrestrial radiation in Ottawa is approximately 282 plus/minus 114 microgray[1] (µGy) per year. The annual doses measured from 2011 to 2015 in the site, local, and regional study areas are shown in Table 5.7.4-3.

While no TLDs are placed within the NSDF project site, one is located near Perch Lake within the Local Study Area. Remaining TLDs in the vicinity of the CRL site are considered to be representative of the RSA, and additional TLDs are located at population centres beyond the RSA. From 2011 to 2015, the Perch Lake TLD has measured annual doses ranging from 314 to 326 µGy (CNL 2016c). The TLDs placed within the RSA have measured annual doses ranging from 285 to 639 µGy from 2011 to 2015 (CNL 2016c). Doses were comparable to the average terrestrial gamma radiation in Ottawa for all LSA monitoring locations except the Main Gate location, which is located within the CRL main campus. This monitoring location recorded the highest doses of all TLDs in the monitoring program, with 2011 to 2015 annual doses ranging from 594 to 639 µGy (CNL 2016c). Annual doses at locations beyond the RSA have ranged from 292 to 499 µGy from 2011 to 2015 (CNL 2016c). Doses at some of these locations exceed the average terrestrial gamma radiation measured in Ottawa (282 ± 114 µGy/yr). Additional discussion regarding the contribution of CRL emissions to ambient gamma dose is included in Section 5.7.4.4.2 Radioactive Noble Gas.

In addition to these TLD doses recorded annually, ambient radiation surveys have been conducted at specific areas throughout CRL, as a means of assessing possible contamination associated with groundwater plumes. Of particular interest with respect to the NSDF are ambient radiation surveys conducted at the East Swamp,

[1] Note: 1 Gy = 1 Sv for external gamma radiation.

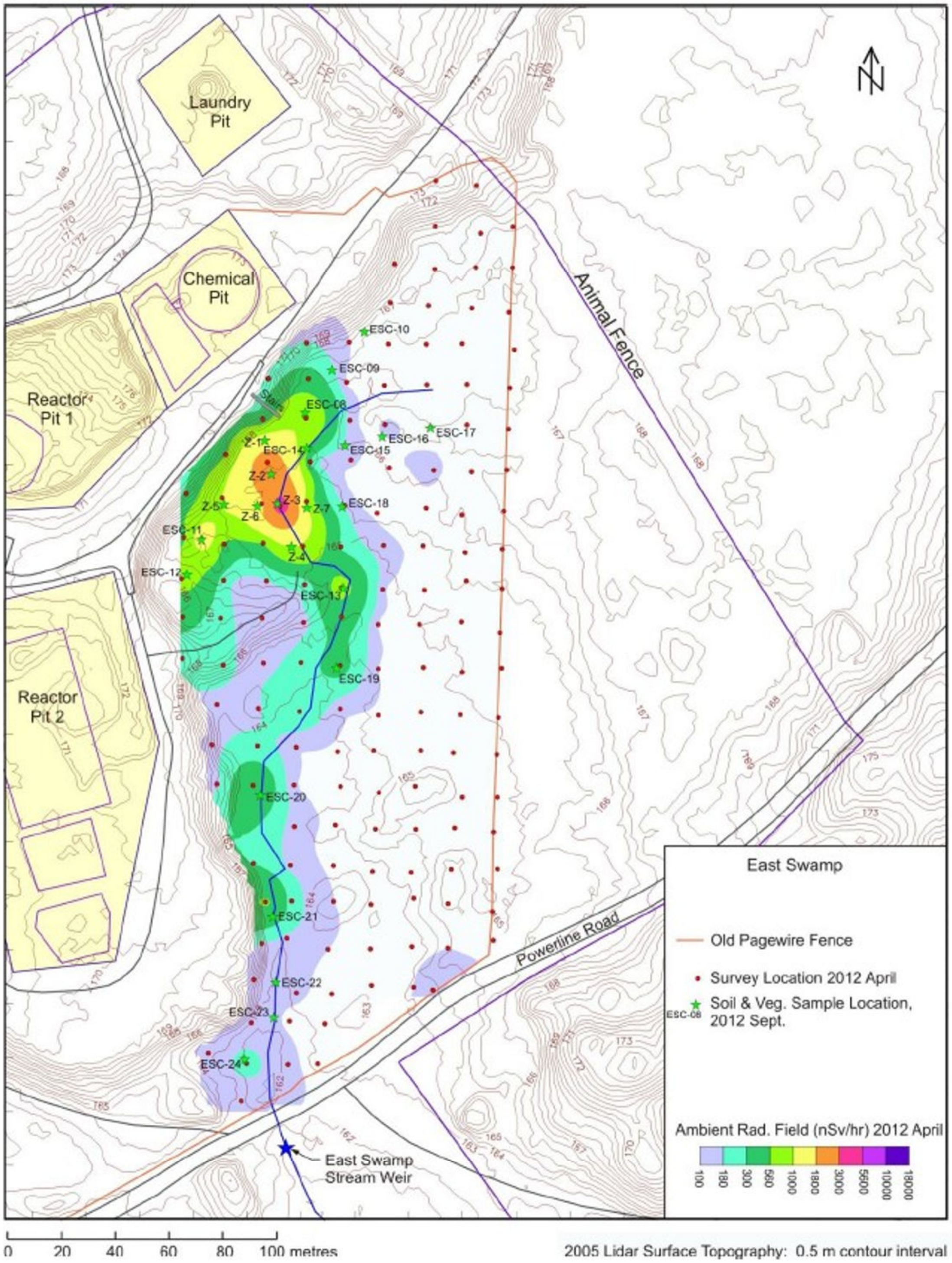
which is immediately west of the NSDF and may be impacted by NSDF operations. The East Swamp has existing contamination due to groundwater plumes from the Chemical Pit and Reactor Pit 2 as a result of legacy operations. Surveys conducted in 2002 and 2012 at the East Swamp have included measurements of ambient radiation over a 15 metre (m) by 15 m grid, covering a 150 m by 250 m area, and collected ambient dose rates at approximately 1 m height. In 2002, the ambient radiation levels in the East Swamp coincided with the Chemical Pit groundwater plume and reached a maximum of 13,500 nanosievert per hour (nSv/hr). In the 2012 survey, radiation field locations were similar, but the maximum dose rate was 4,000 nSv/hr. Dose rates primarily resulted from gamma-emitting radionuclides in surface soil and vegetation. Monitoring of these media is discussed in Section 5.7.4.7 Radioactivity in Soil and Section 5.7.4.7, respectively. Ambient radiation fields measured in East Swamp in 2012 are shown in Figure 5.7.4-6 (CNL 2015c).

Table 5.7.4-3: Annual Ambient Gamma Dose Measured by TLDs (µGy)

	2011	2012	2013	2014	2015	2011-2015 Average
Local Study Area						
Perch Lake Main (A33)	318	323	314	317	326	319.6
Regional Study Area						
East Mattawa Rd. (A32)	352	348	328	334	348	342.0
C-2 Fire trail (A03)	347	358	337	347	356	349.0
C-2 Fire trail at hydro line (A34)	307	324	294	301	302	305.6
Pointe au Baptême (A01)	345	345	310	321	334	331.0
Main Gate (A09)	639	631	627	594	634	625.0
Balmer Bay (A08)	417	402	365	376	403	392.6
Bldg. 560 Outdoors (A43)	288	311	285	336	345	313.0
Ottawa St. Chalk River (A05)	404	416	413	421	428	416.4
Mountain View Subdivision (A06)	332	337	338	319	312	327.6
Beyond Regional Study Area						
MacDonald, Deep River (A12)	406	390	387	387	413	396.6
Harrington Bay (A15)	445	467	440	434	458	448.8
Pembroke, Lloyd St. (A22)	321	365	313	323	331	330.6
NPD Des Joachims (A28)	482	480	499	461	481	480.6
NPD Hwy 17 Gate (A29)	411	435	401	409	452	421.6
NPD Reactor Site (A30)	414	449	418	404	429	422.8
Petawawa Filtration Plant (A35)	367	418	369	368	375	379.4
Demers Centre (A40)	374	400	363	393	402	386.4
Rankin (A42)	382	372	368	348	378	369.6
Sheenboro (A45)	332	317	328	292	307	315.2

Source: CNL 2016c

TLD = Thermoluminescent Dosimeters; NPD = Nuclear Power Demonstration; µGy = microgray.



CLIENT
CANADIAN NUCLEAR LABORATORIES

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT

TITLE
2012 EAST SWAMP AMBIENT GAMMA SURVEYING RESULTS

CONSULTANT

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	MM
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0012	0.0	**5.7.4-6**

REFERENCE(S)
1. BASEMAP PROVIDED BY CNL

S:\Clients\Canadian_Nuclear_Laboratories\NSDF\99_PROJ\1547525_NSDF_EIS\40_PROD\0009_EIS_Section_5\Section_5.7_Ambient_Radioactivity\1547525-0009-G-0006.mxd

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm

5.7.4.4.2 Radioactive Noble Gas

At five locations of interest, continuous monitoring of dose rate from airborne noble gases is performed. This is accomplished with dual Geiger tube GammaTRACER systems, allowing the external gamma dose rate resulting from CRL operations to be distinguished from background. This contribution is primarily from the noble gas Ar-41. Measurements of total noble gas ambient dose equivalent are shown in Table 5.7.4-4.

No monitoring of noble gas is performed within the footprint of the NSDF Project site. One GammaTRACER is placed at the south-western edge of the CRL property, and one is at the north-western edge near Balmer Bay. These locations are considered to be within the RSA.

From 2011 to 2015, the annual gamma dose within the RSA attributable to noble gases released from CRL operations have ranged from 9.3 microsieverts (µSv) to 67.2 µSv. Doses are generally higher near Balmer Bay since it is in the path of prevailing wind from the atmospheric releases on-site (CNL 2016c). It is noted that due to variability in releases and environmental conditions, this observation is not necessarily true each year (e.g., noble gas dose is higher at Harrington Bay in 2015). Three GammaTRACERs are placed at population centres beyond the RSA. From 2011 to 2015, the annual gamma dose at these locations attributable to noble gases released from CRL operations have ranged from 13.8 to 90.6 µSv.

Table 5.7.4-4: Noble Gas Annual Dose Measured by GammaTRACERs (µSv)

	2011	2012	2013	2014	2015	2011-2015 Average
Regional Study Area						
Building 560 (GT43)	9.3	15.5	11.7	11.7	18.7	13.4
Balmer Bay (GT08)	64.9	67.2	67.2	55.9	66.4	64.3
Beyond Regional Study Area						
Harrington Bay (GT15)	17.7	32.2	22.2	N/A	90.6	40.7
Deep River (GT24)	13.8	30.4	27.0	26.5	32.1	26.0
Petawawa (GT35)	14.8	29.4	20.2	24.1	40.8	26.0

Source: CNL 2016c.
Note: GammaTRACER units are calibrated to ambient dose equivalent, H*(d), with d = 10 mm (ICRP 1991).
µSv = microsieverts; N/A = not available.

Measurements of noble gas dose at the locations above provide an indication of the contribution of CRL emissions to the annual ambient gamma doses described in Section 5.7.4.4.1 Ambient Gamma Dose. By subtracting noble gas doses from TLD measurements[2], the terrestrial background dose in the absence of CRL noble gas emissions may be distinguished. This is shown in Table 5.7.4-5 for the four locations where TLDs and GammaTRACERs are co-located. It is observed that after subtracting the contribution of CRL noble gas emissions, the terrestrial gamma dose at three of the four locations is comparable to the average terrestrial gamma dose for Ottawa (282 ± 114 µGy/yr). The terrestrial gamma dose at the Harrington Bay location is slightly above the upper bound of this background value, indicating that the background dose at this location is slightly above the average background calculated for Ottawa.

Table 5.7.4-5: Average Annual CRL Noble Gas Dose Compared to Ambient Gamma Dose

	2011-2015 Average Ambient Gamma Dose Measured by TLD (µGy)	2011-2015 Average Noble Gas Dose Measured by GammaTRACER (µGy)	2011-2015 Ambient Gamma Dose Without CRL Noble Gas Contribution (µGy)
Balmer Bay (GT08)	393	54	339
Building 560 (GT43)	313	11	302
Harrington Bay (GT15)	453[a]	34	419
Petawawa (GT35)	379	22	358

a) This average omits the value recorded in 2014, in order to achieve consistency with respect to the GammaTRACER dataset, which does not include a measurement from 2014.

5.7.4.4.3 Tritium in Air

Ambient tritium in air is monitored at locations throughout the CRL main campus, at the property boundary, and at population centres off-site. Tritium is monitored using passive diffusion samplers. These are liquid scintillation vials containing a solution of 50% glycol and 50% water, designed to sample air at a rate of one litre per day. These samples are collected and analyzed quarterly using liquid scintillation counting. The reported annual average tritium concentrations are calculated based on these quarterly measurements, and uncertainties are reported in the Environmental Monitoring Report based on counting statistics (CNL 2016c).

No ambient tritium monitors are within the boundary of the NSDF Project site. The Perch Lake Main monitoring station is located within the LSA. From 2011 to 2015, the average tritium concentrations in air at this location are less than 5.1 Becquerel's per cubic metre (Bq/m^3).From 2011 to 2015, average tritium concentrations in the RSA range from less than 0.4 Bq/m^3 at the C-2 Fire Trail location to 9.9 Bq/m^3 at the on-site Sewage Treatment Plant. Tritium monitoring is performed at off-site population centres beyond the RSA. Tritium concentrations at these locations are below the detection level, and have averaged less than 0.5 Bq/m^3 from 2011 to 2015 (Table 5.7.4-6).

[2] Prior to subtracting noble gas dose from TLD values, the noble gas doses in µSv were converted to absorbed dose in air (air kerma) using a conversion factor of 1.2 µSv/µGy (US DOE 1997).

Elevated tritium concentrations have been measured at the Sewage Treatment Plant and Main Gate locations. These locations are close to the NRU stack, which is the primary source of tritium emissions at the CRL site. Additionally, elevated tritium concentrations have been observed at the WMA B Gate monitoring station. This location is near WMA B, which has been a source of airborne tritium releases.

Table 5.7.4-6: Annual Average Tritium Concentration in Air (Bq/m^3)

	2011	2012	2013	2014	2015	2011-2015 Average
Local Study Area						
Perch Lake Main (A33)	3.64	3.53	13.4	<2.4	2.5	<5.1
Regional Study Area						
East Mattawa Rd. (A32)	2.11	1.74	1.7	N/D	1.5	<1.8
C-2 Fire trail (A03)	<0.50	<0.52	<0.2	<0.3	<0.4	<0.4
Main Gate (A09)	3.3	4.1	4.0	4.3	3.2	3.8
Pointe au Baptême (A01)	1.34	1.30	1.0	1.2	1.3	1.2
Sewage Treatment Plant (A568)	9.25	11.4	2.4	9.8	16.4	9.9
Balmer Bay, W Mattawa Rd. (A08)	<0.49	<0.48	<0.5	<0.8	<0.7	<0.6
WMA B Gate (A44)	4.08	7.08	15.9	4.8	3.1	6.99
Mountain View Subdivision (A06)	<0.45	<0.46	<0.0	N/D	N/D	<0.30
Beyond Regional Study Area						
MacDonald, Deep River (A12)	<0.45	<0.46	<0.1	<0.2	<0.5	<0.34
Harrington Bay (A15)	<0.46	<0.47	N/D	<0.2	<0.4	<0.38
Petawawa Filtration Plant (A35)	<0.54	<0.46	N/D	N/D	N/D	<0.50
Demers Centre (A40)*	<0.45	<0.46	N/D	N/A	N/A	<0.46
Sheenboro (A45)	<0.45	<0.46	<0.1	<0.2	<0.3	<0.30

Source: CNL 2016c, Table 7-9 and 7-10. Note: Table 7-10 includes transcription errors for A03, A08, and A32. These are corrected based on Table 7-9 and 2014 Environmental Monitoring Report (CNL 2015a).

<= indicates results below the detection level, or an average calculated using one or more results below detection level.

* = monitoring at Demers Centre was discontinued at the end of 2013.

Bq/m3 = Becquerels per cubic metre.

N/D = indicates results below the critical level (i.e., not detected).

N/A = Not available.

5.7.4.4.4 Carbon-14 in Air

Carbon-14 is monitored in air at locations on the CRL main campus, at the property boundary, and off-site at local population centres. Carbon-14 is monitored with the use of passive samplers employing mixed calcium-sodium hydroxide pellets. Carbon-14 evolved from the pellets was analyzed by liquid scintillation counting. No C-14 monitoring is within the boundaries of the NSDF Project site. The Perch Lake Main monitoring location is close to the NSDF Project site, and is considered to be representative of the LSA. Carbon-14 is monitored at three locations within the CRL main campus, which are considered to be within the RSA. Four C-14 monitoring locations exist in population centres beyond the RSA. These are in Deep River, Harrington Bay, Petawawa, and Sheenboro. At all locations, concentrations of C-14 in air are close to or below the detection level (Table 5.7.4-7).

Table 5.7.4-7: Annual Average Carbon 14 Concentration in Air (Bq/m^3)

	2011	2012	2013	2014	2015	2011-2015 Average
Local Study Area						
Perch Lake Main (A33)	0.10	0.06	<0.11	<0.07	0.13	<0.09
Regional Study Area						
Pointe au Baptême (A01)	<0.10	0.08	<0.14	<0.06	<0.03	<0.08
Balmer Bay, W Mattawa Rd. (A08)	0.06	<0.07	<0.004	<0.08	<0.07	<0.06
CRL, near Bldg 580 (A43)	0.07	<0.06	<0.08	<0.07	<0.08	<0.07
Beyond Regional Study Area						
MacDonald, Deep River (A12)	0.08	<0.07	N/D	<0.08	<0.06	<0.07
Harrington Bay (A15)	0.06	<0.06	<0.05	<0.06	<0.04	<0.06
Petawawa Filtration Plant (A35)	<0.06	<0.09	<0.06	<0.07	<0.05	<0.07
Sheenboro (A45)	0.08	0.06	<0.08	<0.08	<0.02	<0.06

Source: CNL 2016c
<= indicates results below the detection level, or an average calculated using one or more results below detection level.
N/D = indicates results below the critical level (i.e., not detected).
Bq/m^3 = Becquerels per cubic metre.

5.7.4.5 Radioactivity in Surface Water

Surface water is monitored at on-site lakes and streams, off-site streams, and locations in the Ottawa River both upstream and downstream of CRL property. The results of radiological monitoring of off-site streams are not discussed in this baseline characterization, as there are no direct liquid emissions to these streams from the NSDF Project.

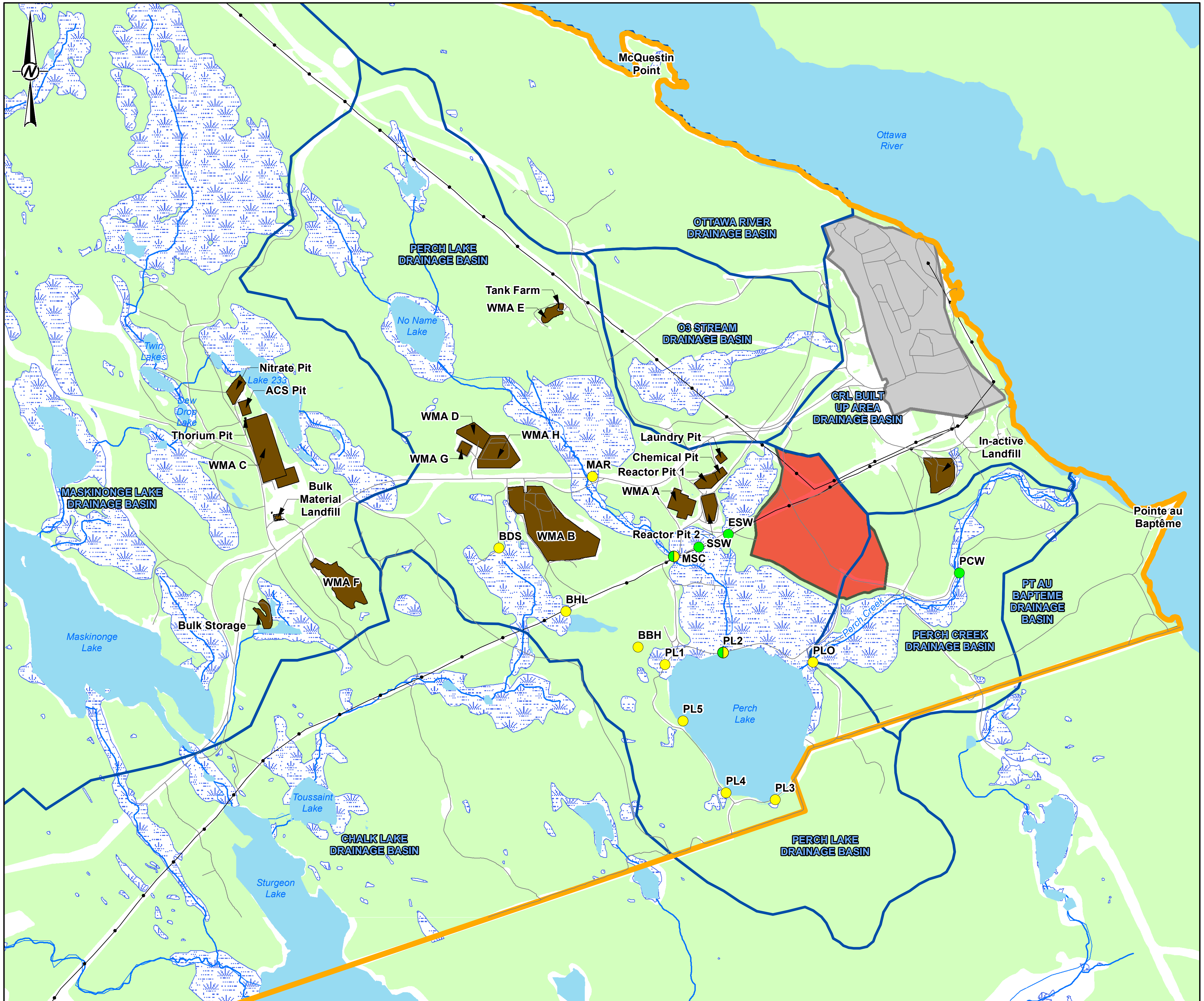
No surface waterbodies are present within the boundaries of the NSDF Project site. The NSDF Project site is located within the Perch Lake basin. Surface waterbodies in the Perch Lake basin are currently affected by the presence of several WMAs, including the CRL Liquid Dispersal Area. The surface water monitoring locations that are closest to the NSDF Project site are the East Swamp Weir, Perch Lake Inlet #2, Perch Lake Outlet, and Perch Creek Weir. The location of these monitoring stations is displayed on Figure 5.7.4-7. Note that while this figure displays non-radiological sampling locations, these are not considered in the assessment of baseline radioactivity.

Table 5.7.4-8 displays the radioactivity in surface waterbodies that are closest to the NSDF Project site. These locations have the highest potential to be affected by NSDF Project operations, and are considered to be within the LSA. Additional surface water monitoring stations exist within the CRL property boundary, within the Maskinonge Lake Basin and upstream locations within the Perch Lake Basin (e.g., B Hydro Line (BHL), Main Stream Culvert [MSC]). These monitoring locations are not included within this baseline characterization, as they are not expected to be affected by the NSDF Project.

The East Swamp Weir is located immediately west of the NSDF Project site. This monitoring location is downstream of the Laundry Pit, Reactor Pit 2, and Chemical Pit. The Perch Lake Inlet #2 monitoring station is located further downstream, and receives discharge from the East Swamp Stream, South Swamp Stream, and Main Stream. The Perch Lake Outlet and Perch Creek Weir monitoring stations represent downstream locations at the exit point of Perch Lake, and along Perch Creek, which flows from Perch Lake to the Ottawa River.

This page intentionally left blank

232 509220 REPT 004
UNRESTRICTED



LEGEND

- ROADS
- RAILWAY
- TRANSMISSION LINE
- RIVER/STREAM
- WATERBODY
- WETLAND
- WOODED AREA
- DRAINAGE BASIN
- NSDF PROJECT SITE
- CRL MAIN CAMPUS
- CRL PROPERTY
- WASTE MANAGEMENT AREA (WMA) [1]
- SAMPLING LOCATION
- WEIR
- SAMPLING LOCATION AND WEIR

500 0 500
1:20,000 METRES

NOTE(S)
1. LIQUID DISPOSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.

REFERENCE(S)
1. BASEDATA ONTARIO MNRF 2016, CANVEC 2016, AND CNL 2016
2. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
3. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18N

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
LOCATIONS OF SURFACE WATER MONITORING STATIONS AND WEIRS

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	MM
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.7.4-7

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:

This page left intentionally blank

The primary radiological contaminants of concern in Perch Lake Basin waters are tritium and gross beta (consisting mainly of Strontium-90 and its daughter Yttrium-90). Tritium levels at Perch Lake Basin monitoring stations near the NSDF Project site have ranged from 286 to 7,518 Becquerel's per litre (Bq/L) from 2011 to 2015. Additionally, elevated gross beta readings have been recorded, particularly at the East Swamp Weir location, where levels have reached 442 Bq/L. Trace amounts of Cobalt-60 (Co-60) and Cesium-137 (Cs-137) have been measured in the Perch Lake basin waters and have been at or below detection levels at the Perch Lake and Perch Creek Weir monitoring stations.

Table 5.7.4-8: Radioactivity (Bq/L) in Surface Waters near the NSDF Project Site

	2011	2012	2013	2014	2015	2011-2015 Average
East Swamp at Weir (ESW), west of NSDF Project site						
Tritium	391	441	328	286	348	359
Gross Alpha	0.397	0.297	0.271	0.204	0.059	0.246
Gross Beta	263	442	261	193	224	277
Total Strontium	104	218	148	80.8	95	129
Cobalt-60	0.540	0.308	0.326	0.180	0.401	0.351
Cesium-137	0.197	0.146	0.134	0.123	0.14	0.15
Perch Creek at Weir (PCW), east of NSDF Project site						
Tritium	4,074	3,498	3,407	2,720	3,172	3,374
Gross Alpha	0.031	0.024	0.024	0.03	<0.022	<0.03
Gross Beta	10.3	8.0	9.0	9.44	11	9.6
Total Strontium	4.59	2.74	2.93	3.80	3.4	3.5
Cobalt-60	<0.015	<0.007	<0.010	<0.01	<0.01	<0.01
Cesium-137	<0.008	<0.006	<0.007	<0.01	<0.008	<0.01
Perch Lake Outlet (PLO), south of NSDF Project site						
Tritium	2,913	7,518	3,996	2,188	2,780	3,879
Gross Beta	12.22	11.21	12.72	12.7	12	12
Perch lake Inlet #2 (PL2), south of NSDF Project site						
Tritium	2,231	1,905	2,531	3,249	2,275	2,438
Gross Alpha	0.0462	0.0431	0.0323	0.038	0.05	0.04
Gross Beta	14.33	21.39	26.37	14.43	14	18
Cobalt-60	0.016	<0.014	<0.014	0.025	0.014	<0.017
Cesium-137	0.009	<0.013	<0.007	0.012	0.013	<0.011

Source: CNL 2016c.

<= indicates results below the detection level, or an average calculated using one or more results below detection level.

Bq/L = Becquerels per litre.

Off-site monitoring of surface water includes inland streams, as well as locations in the Ottawa River both upstream and downstream of CRL property. There are no liquid emissions to off-site streams from the proposed NSDF Project, therefore these are not described in the background characterization.

Radioactivity at upstream and downstream locations in the Ottawa River is displayed in Table 5.7.4-9. Annual average background tritium concentrations are less than 4 Bq/L at locations upstream of CRL. Of particular relevance to the NSDF Project is the Pointe au Baptême monitoring location. This is downstream of CRL near the property boundary, and is immediately downstream of the Perch Creek outlet, which could potentially be affected by the NSDF. The tritium concentrations at this location are slightly above background, with annual average values up to 64 Bq/L from 2011 to 2015.

Monitoring stations located further downstream on the Ottawa River are considered to be representative of the area beyond the RSA. Concentrations of radiological contaminants at these locations are low, with annual average tritium concentrations less than 9 Bq/L.

Table 5.7.4-9: Average Radioactivity (Bq/L) in the Ottawa River, Upstream and Downstream of Chalk River Laboratories

	2011	2012	2013	2014	2015	2011-2015 Average
Rolphton (ORR), 28 km upstream						
Tritium	<3	<4	<1	<1.2	<1.7	<2.2
Gross Beta	0.045	0.056	<0.039	0.042	0.04	0.046
Gross Alpha	0.0064	0.0056	0.0046	0.0115	0.0091	0.0074
Total Strontium	0.0034	<0.0037	<0.0017	0.0048	0.0019	<0.0031
Cesium-137	0.001	<0.0009	<0.0010	<0.0016	<0.0012	<0.0011
Deep River (ORD), 9 km upstream						
Tritium	<3	<3	<1	<1	<1.4	<1.9
Gross Beta	0.042	0.061	0.042	0.046	0.039	0.046
Gross Alpha	0.0046	0.0056	0.0045	0.0095	0.0079	0.0064
Total Strontium	0.0039	<0.0027	0.0026	<0.0052	<0.0027	<0.0034
Cesium-137	<0.0008	0.0011	<0.0009	<0.0007	<0.002	<0.0011
Pointe au Baptême (PAB), CRL downstream boundary						
Tritium	26	64	<43	41	48	<44
Gross Beta	0.16	0.19	0.15	<0.23	<0.12	<0.17
Gross Alpha	0.009	0.008	0.0068	0.0073	0.014	0.0090
Highview (OR5), 8 km downstream						
Tritium	<9	<11	N/D	N/D	<6.34	<8.78
Gross Beta	<0.049	<0.045	0.07	0.04	0.001	<0.041
Harrington Bay (ORH), 9 km downstream						
Tritium	<4	<3	<2	<2	1.4	<2.48
Gross Beta	0.043	0.033	0.036	0.05	0.028	0.038
Gross Alpha	0.0055	0.0039	0.0033	0.021	0.0078	0.0083
Total Strontium	0.004	<0.003	0.003	0.003	<0.0008	<0.0028
Cesium-137	<0.0012	<0.0018	<0.0016	<0.0020	<0.0018	<0.00168

Source: CNL 2016c.

<= indicates results below the detection level, or an average calculated using one or more results below detection level.

Bq/L = Becquerels per litre; km = kilometres; N/D = indicates results below the critical level (i.e., not detected).

5.7.4.6 Radioactivity in Groundwater

Groundwater is monitored at locations throughout the CRL site as part of the CRL Groundwater Monitoring Program (GWMP). This program evaluates and reports groundwater concentrations of a large suite of radiological and non-radiological parameters for samples collected from approximately 180 monitoring wells located at 32 different monitoring sites. Monitoring sites include CRL Waste Management Areas, lands previously affected by past operational activities, and the developed part of the CRL site. These monitoring activities are performed annually or twice-yearly around the perimeters of operating areas as a means of monitoring the conditions and behaviour of the facilities and operations. Results of the GWMP are presented each year in the GWMP annual report. These data provide operational feedback on the conditions and behaviour of facilities, including the performance of existing remedial measures (e.g., infiltration barriers). The GWMP includes wells that are upgradient of the monitored areas, in order to provide reference values.

Where groundwater contamination is present, this routine monitoring is augmented by periodic detailed evaluations of subsurface contaminant distributions and movement. These provide characterization of existing contaminant plumes. The monitoring of contaminant plumes provides the basis for observing environmental impacts and evaluating future impacts, including confirming the applicability of remedial measures.

Groundwater monitoring is performed in the LSA at locations within the CRL property where contamination is of concern. Reference wells located upstream of WMAs are considered representative of ambient radiological contaminant concentrations in these areas. The highest concentrations and widest variety of radioactive contaminants in groundwater on the CRL property are located downgradient of the Chemical Pit (CNL, 2016a). Total beta activity associated with strontium-90 in groundwater between the Chemical Pit and the East Swamp is on the order of 10,000 to 70,000 Bq/L. Gross alpha, cesium-137 and cobalt-60 in groundwater are also elevated (CNL, 2016a). Characterization of the groundwater plume from the Chemical Pit has also included the sampling of pore water from the East Swamp (indicative of groundwater discharging to the surface water). Gross alpha, total beta, and Sr-90 activities were found to range from <3 to <8 Bq/L, 230 to 4,900 Bq/L, and 120 to 2,960 Bq/L respectively (CNL, 2015b). Downgradient of Waste Management Area A, total beta activity in groundwater was generally between 3,000 and 10,000 Bq/L with a peak of 30,000 Bq/L. Downgradient of Reactor Pit 2, total beta activity in groundwater was generally between 2,000 and 15,000 Bq/L with a peak of 22,100 Bq/L (CNL, 2015a).

The reference wells closest to the NSDF Project site are labelled LDA-3 and GD-42. LDA-3 is located upgradient of Reactor Pit #1, west of the NSDF Project site. The GD-42 well is located upgradient of the inactive landfill, northeast of the NSDF Project site, although this is not directly applicable to the baseline characterization as it is located in a different drainage basin. The location of WMAs adjacent to the NSDF Project and routine groundwater monitoring locations are shown in Figure 5.7.4-8. The location of individual monitoring wells relative to the Reactor Pit and Inactive Landfill are shown in Figure 5.7.4-8 and Figure 5.7.4-9 respectively. The concentration of radiological contaminants, as measured by spring and fall measurements, in these reference (i.e., background) wells is shown in Table 5.7.4-10.

Table 5.7.4-10: Radioactivity in Reference Wells near the NSDF Project Site (Bq/L)

	2010	2011	2012	2013	2014	2010-2014 Average
Reference wells near NSDF Project site						
LDA-3, upgradient of Reactor Pit #1, West of NSDF Project site (Same drainage basin as NSDF)						
Tritium	112.23	102.5	52.1	97.3	67.7	86.4
Total alpha	<0.12	<0.12	<0.13	<0.25	<0.14	<0.15
Total beta	<0.4	<0.39	<0.4	<0.51	<0.38	<0.4
GD-42*, upgradient of the inactive landfill, Northeast of NSDF Project site (Different drainage basin as NSDF)						
Tritium	N/A	178	195	399	398	292
Total alpha	N/A	<0.18	<0.15	<0.24	<0.26	<0.21
Total beta	N/A	<0.57	<0.45	<0.26	<0.32	<0.4

Source: CNL 2012, 2013, 2014a, 2015b, 2016e.
<= indicates results below the detection level, or an average calculated using one or more results below detection level.
* = monitoring of the GD-42 wells began in 2011.
Bq/L = Becquerels per litre.
N/A = not available.

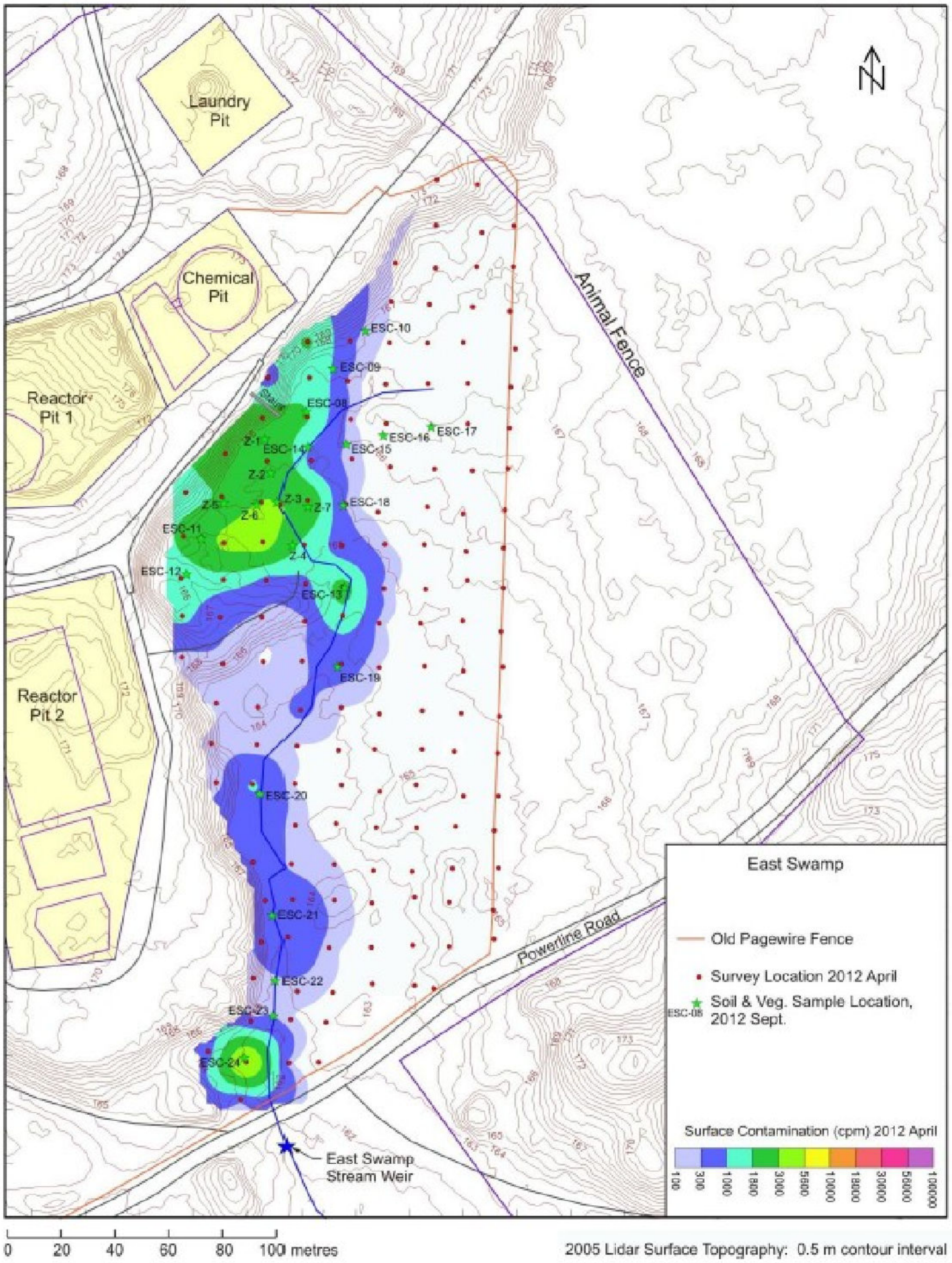
Investigations of contamination in East Swamp have included measurements of radioactivity in pore water (CNL 2015c). The East Swamp has existing contamination due to groundwater plumes from the Chemical Pit and Reactor Pit 2. Since it is immediately west of the NSDF site, this contamination is relevant to the baseline radioactivity characterization for the SSA. Surveying conducted in 2012 included collection and analysis of pore water at 7 locations, labelled Z-1 to Z-7 in Figure 5.7.4-10. The radiological contamination in these samples is shown in Table 5.7.4-11. All gross alpha concentrations in these pore water samples were less than detection limits (<8 Bq/L). Total beta ranged from 180 Bq/L to a maximum of 4,900 Bq/L. Strontiumr-90 concentrations ranged from 120 Bq/L to a maximum of 2,960 Bq/L. The East Swamp contamination study utilized these concentrations to estimate distribution coefficients of radionuclides in soil, which is the ratio of radionuclide concentrations in the solid phase to the concentrations in solution.

Table 5.7.4-11: Radioactivity in Pore Water Samples from 2012 East Swamp Survey (Bq/L)

Location ID	Gross Alpha	Total Beta	Sr-90
Z-1	<3	1,300	770
Z-2	<7	4,900	2,960
Z-3	<6	520	308
Z-4	<3	980	500
Z-5	<3	1,600	950
Z-6	<6	180	120
Z-6 Replicate	<8	230	130
Z-7	<3	780	482

<= indicates results below the detection level.
Bq/L = Becquerels per litre.

Further groundwater sampling at the NSDF Project Site was completed by AMEC in October and December 2016 (AMEC 2016 and AMEC 2017). Tritium, gross alpha, and total beta activities were found to range from <64 to 155 Bq/L, <0.009 to 0.552 Bq/L, and <0.01 to 1.06 Bq/L respectively. These results are slightly elevated in comparison to ambient radiological conditions in groundwater observed near the NSDF Project Site for some parameters (i.e., gross alpha). It is noted that these ranges are based on two monitoring events for the NSDF Project Site.



CLIENT
CANADIAN NUCLEAR LABORATORIES

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT

TITLE
2012 EAST SWAMP SURVEY GRID DISPLAYING PORE WATER SAMPLING LOCATIONS Z-1 TO Z-7

CONSULTANT

Golder Associates

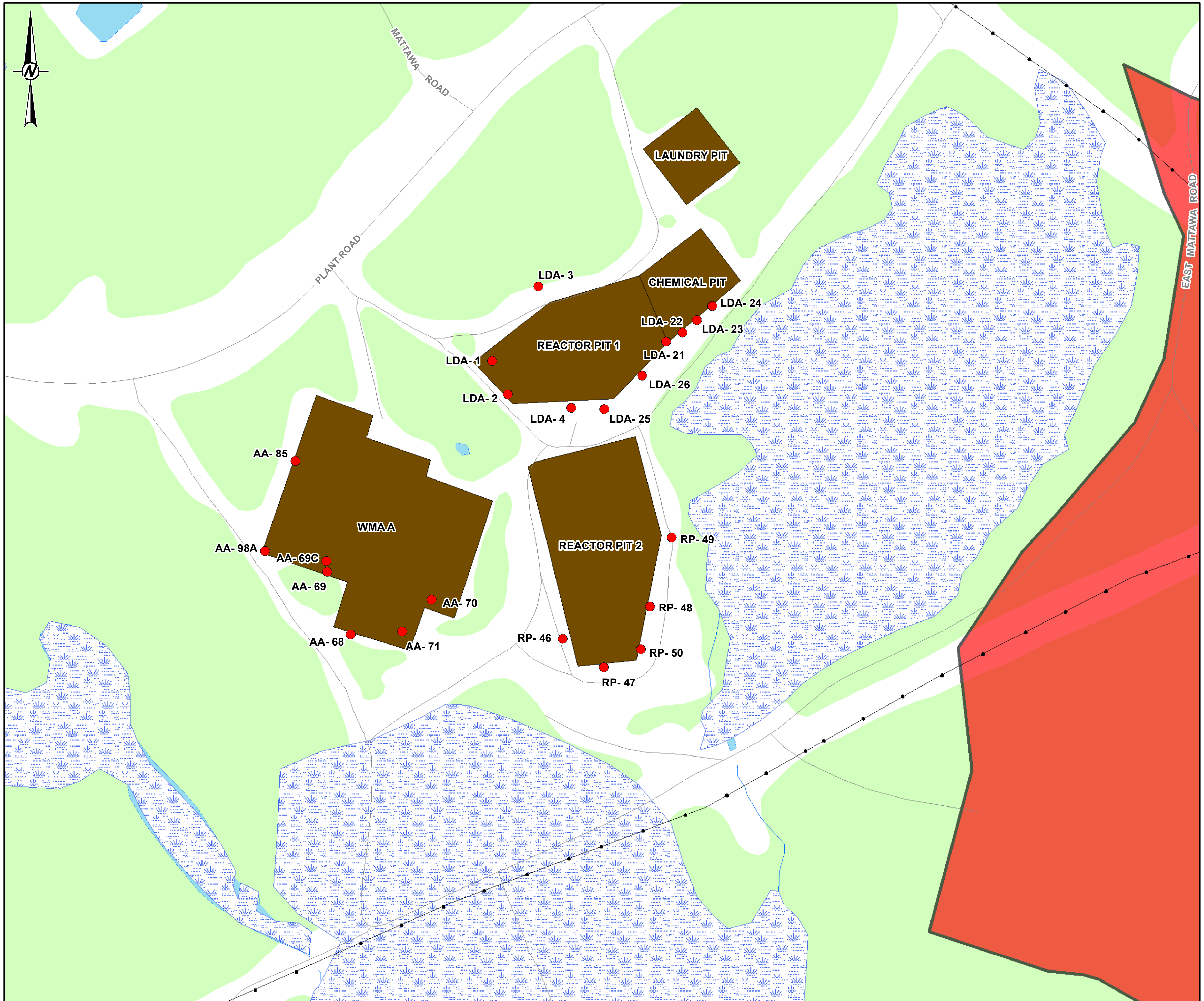
YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	MM
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0012	0.0	**5.7.4-8**

REFERENCE(S)
1. BASEMAP PROVIDED BY CNL

S:\Clients\Canadian_Nuclear_Laboratories\NSDF\99_PROJ\1547525_NSDF_EIS\40_PROD\0009_EIS_Section_5\Section_5.7_Ambient_Radioactivity\1547525-0009-G-0006.mxd

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:
0
25mm



LEGEND

- ROAD
- TRANSMISSION LINE
- RIVER/STREAM
- WATERBODY
- WETLAND
- NSDF PROJECT SITE
- WASTE MANAGEMENT AREA (WMA)[1]
- CRL PROPERTY
- GWMP MONITORING WELL

50 0 50
1:2,500 METRES

NOTE(S)
1. LIQUID DISPOSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.

REFERENCE(S)
1. BASEDATA ONTARIO MNRF 2016, CANVEC 2016, AND CNL 2016
2. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
3. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE18N

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

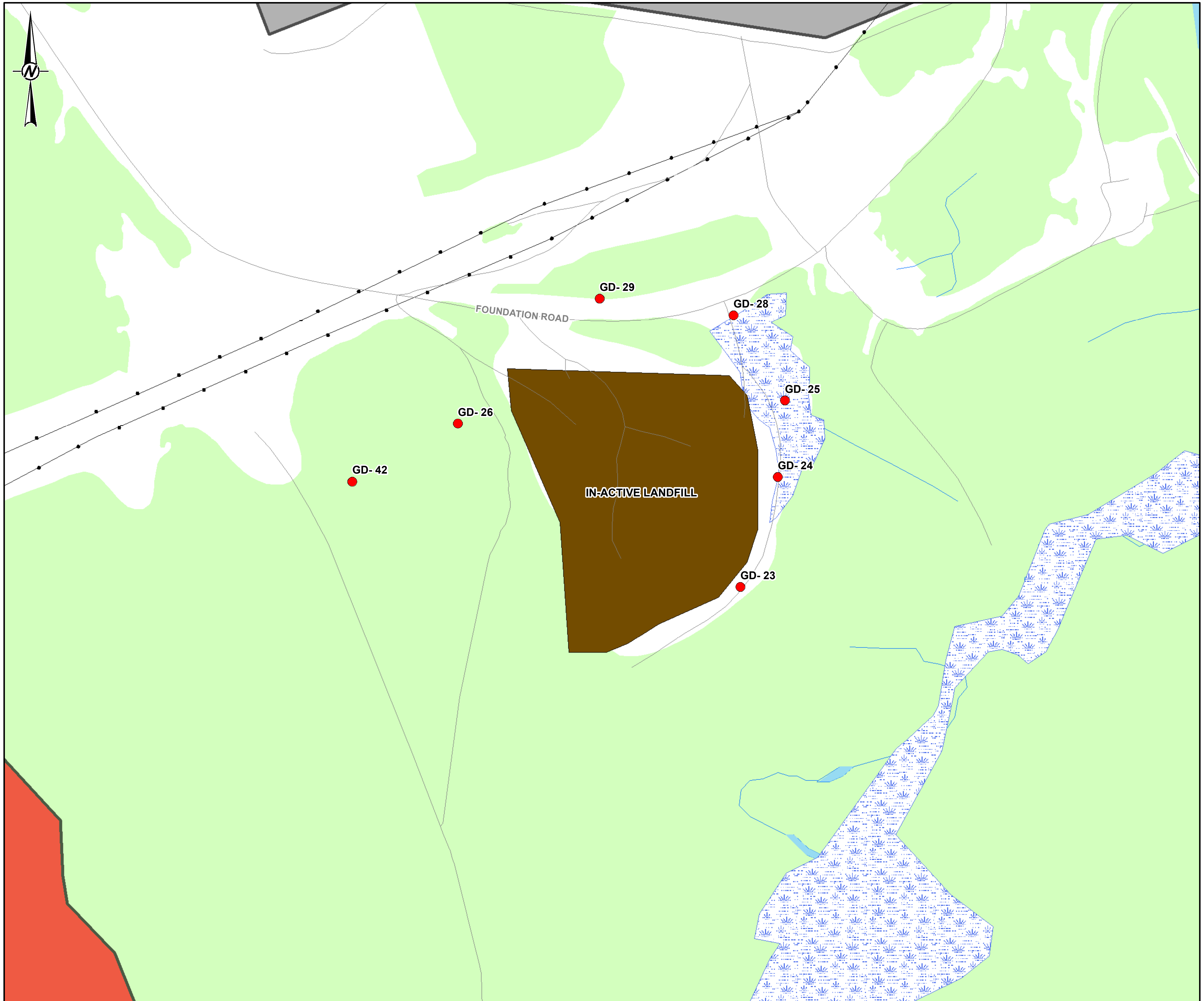
TITLE
LOCATION OF WASTE MANAGEMENT AREAS AND GROUNDWATER MONITORING AREAS

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	MM
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.7.4-9

This page left intentionally blank



LEGEND

- ROAD
- TRANSMISSION LINE
- RIVER/STREAM
- WATERBODY
- WETLAND
- NSDF PROJECT SITE
- CRL MAIN CAMPUS
- WASTE MANAGEMENT AREA (WMA)[1]
- CRL PROPERTY
- GWMP MONITORING WELL

50 0 50
1:2,500 METRES

NOTE(S)
1. LIQUID DISPOSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.

REFERENCE(S)
1. BASEDATA ONTARIO MNRF 2016, CANVEC 2016, AND CNL 2016
2. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
3. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE18N

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
LOCATION OF INDIVIDUAL GROUNDWATER MONITORING WELLS RELATIVE TO INACTIVE LANDFILL

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	MM
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.7.4-10

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm

S:\Clients\Canadian_Nuclear_Laboratories\NSDF\99_PROJ\1547525_NSDF_EIS\40_PROD\0009_EIS_Section_5\Section_5.7_Ambient_Radioactivity\1547525-0009-G-0010.mxd

This page left intentionally blank

5.7.4.7 Radioactivity in Soil

Recent geotechnical investigations in 2016 (Golder 2016a) included a radiological screening of soil samples prior to off-site non-radiological analysis. No radiological contamination was discovered at the NSDF Project site, although it is noted that no quantitative analysis was performed for radiological contaminants beyond screening with a contamination meter.

Measurements of radionuclide concentrations in soil have been performed at specific areas of concern within the CRL property. This has included studies of ambient radiation as well as soil, groundwater, and vegetation contamination in areas impacted by groundwater plumes from WMAs at CRL.

Radiological contamination in the East Swamp wetland is relevant to the NSDF Project, as this area is immediately west of the NSDF Project site. Because this wetland is potentially downgradient of parts of the NSDF Project site, characterization of the contamination present is important in defining baseline conditions. The East Swamp wetland has existing contamination associated with a shallow subsurface plume from the Chemical Pit, and a second plume from Reactor Pit 2. The surface contamination distribution in the East Swamp has been characterized on a 5-year frequency with radiation field surveys, surface surveys, and vegetation contamination surveys performed in 2002, 2007 and 2012. In 2002 and 2012, these surveys included wetland soil and vegetation sampling to determine the radionuclide concentrations in these media. Surveying was conducted over a 150 m by 350 m area, using a 15 m by 15 m grid spacing. Additional relevant surveying has been performed to characterize the Chemical Pit plume; this has included measurements of radionuclides in soil (CNL 2014b). Based on the 5-year frequency, surveying in East Swamp will again be conducted in 2017.

Sub-surface Soil in the Chemical Pit Plume

Surveying of the Chemical Pit plume conducted in 2002 included measurements of subsurface soil immediately downgradient of the Chemical Pit, in the East Swamp (CNL 2014b). Figure 5.7.4-10 provides an indication of the spatial extent of the Chemical Pit Plume in the East Swamp. Total beta concentrations in borehole samples ranged from 580 to 345,000 Becquerel's per kilogram (Bq/kg). Gross alpha activity ranged from <110 to 760 Bq/kg. Gamma spectroscopy was performed on samples with more than 2000 Bq/kg of total beta activity, and the anthropogenic gamma emitters Co-60, Cs-137, and Americium-241 (Am-241) were detected. Concentrations of Co-60 in soil ranged from background (<10 Bq/kg) to 2680 Bq/kg. Concentrations of Cs-137 in soil ranged from background (<20 Bq/kg) to 970 Bq/kg. Concentrations of Am-241 ranged from background (<70 Bq/kg) to 1,110 Bq/kg.

Surficial Soil in the East Swamp

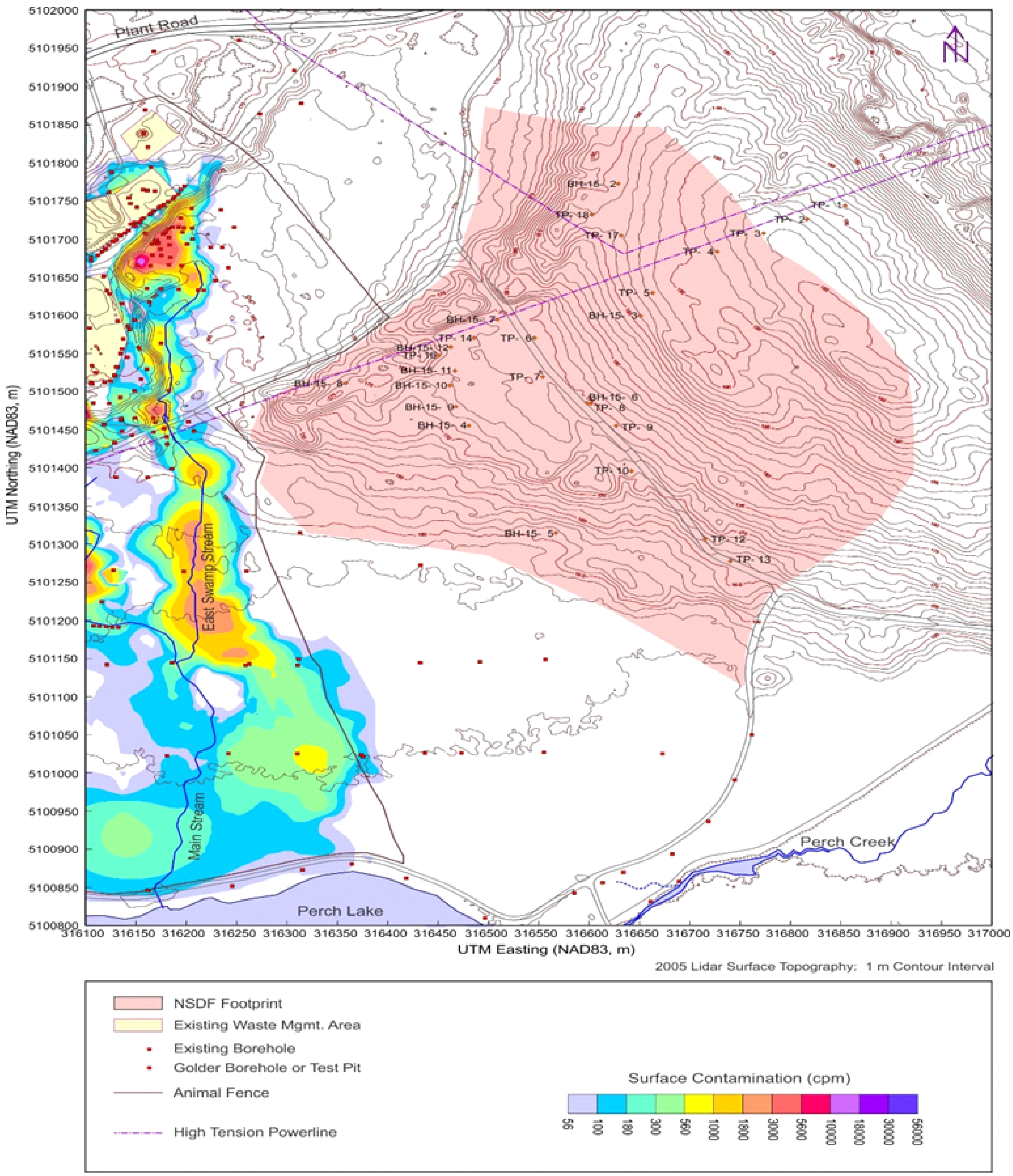
The 2002 East Swamp soil survey found total beta concentrations ranging from 850 Bq/kg at background locations east of the contaminated region to 1,845,000 Bq/kg at locations where the plume discharges to surface (CNL 2015c). Alpha activity concentrations ranged from background levels (100 Bq/kg) in reference locations to a maximum of 8570 Bq/kg in the Chemical Pit groundwater discharge zone. Co-60 soil concentrations in East Swamp range from background (100 Bq/kg) to 151,000 Bq/kg. Cs-137 soil concentrations range from 3,000 Bq/kg to 5,700 Bq/kg. For Co-60 and Cs-137, the highest concentrations were observed within the Chemical Pit groundwater plume discharge zone.

The 2012 soil survey found total beta concentrations ranging from 1,040 Bq/kg to 1,562,000 Bq/kg, with the maximum levels occurring where the Chemical Pit groundwater plume discharges to surface (CNL 2015c). Alpha activity concentrations ranged from 170 Bq/kg to 74,300 Bq/kg, with the maximum occurring in the Chemical Pit groundwater discharge zone. Co-60 concentrations were measured ranging from 20 Bq/kg to 102,000 Bq/kg, while Cs-137 concentrations ranged from 40 Bq/kg to 105,000 Bq/kg. Both maxima occurred within the Chemical Pit groundwater plume.

Figure 5.7.4-11 displays a map of surface contamination in the Perch Lake Wetland based on a compilation of data collected in 2009, 2011, 2012, and with some data from 1997. This map is useful for visualizing the spatial extent of contamination in the Perch Lake wetland, and locations of contamination with respect to the NSDF site.

No monitoring of soil is performed in the RSA as part of the CRL Environmental Monitoring Program. The Canadian Nuclear Safety Commission Independent Environmental Monitoring Program (CNSC 2016) has included measurements of radioactivity in soil near the towns of Chalk River (approximately 8 km southwest of CRL) and Chapeau (approximately 25 km southeast of CRL). In 2014, Cs-137 measured in soil near Chalk River was present at a concentration of 5.81 Bq/kg dry weight, while at Chapeau, 6.54 Bq/kg dry weight was measured (CNSC 2016).

Site-specific background values for radiological contaminants in soil have been established by the CRL Environmental Backgrounds, Limits, and Benchmarks Report (CNL 2017a). Soil data from 43 locations on the Chalk River site, generally unaffected by CNL operations, were used to calculate the upper limit of background concentrations. Background concentrations of additional radiological parameters were taken from north-eastern Ontario regional measurements or the Ontario MOECC's background site condition standard values. Upper-limit background values for Cs-137 in soil have been calculated in the CRL Environmental Backgrounds, Limits, and Benchmarks Report as 23.8 Bq/kg (CNL 2017a). It is noted that higher background values may exist. For example, Milton et al. (2001) measured Cs-137 concentrations in soil of approximately 200 Bq/kg at the CRL site, and approximately 35 Bq/kg at Petawawa.



NOT TO SCALE

REFERENCE(S)
1. BASEMAP PROVIDED BY CNL

CLIENT
CANADIAN NUCLEAR LABORATORIES

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT

TITLE
EXISTING SURFACE CONTAMINATION IN THE PERCH LAKE WETLAND WEST AND SOUTH OF THE NSDF PROJECT SITE

CONSULTANT

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	MM
APPROVED	AB

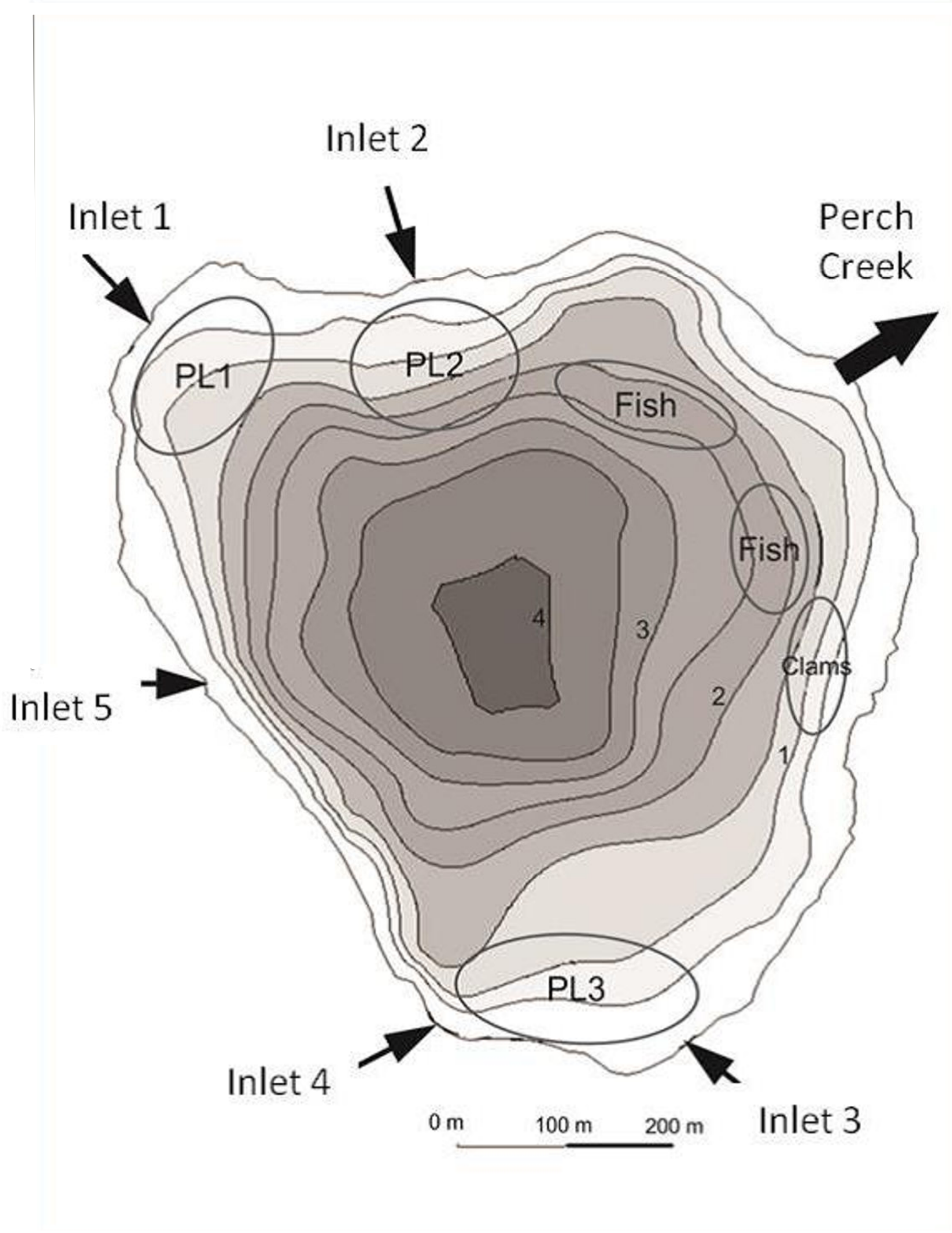
PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0012	0.0	5.7.4-11

S:\Clients\Canadian_Nuclear_Laboratories\NSDF\99_PROJ\1547525_NSDF_EIS\40_PROD\0009_EIS_Section_5\Section_5.7_Ambient_Radioactivity\1547525-0009-G-0011.mxd

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm

5.7.4.8 Radioactivity in Aquatic Sediment

No sediment is present within the SSA (i.e., the footprint of the NSDF Project site). Sediment has been monitored periodically in Perch Lake, which may be impacted by the NSDF and is considered to be representative of the LSA. Sampling locations for studies completed in 2003 and 2013 are shown in Figure 5.7.4-12 (CNL ETB 2016). The measurements of tritium oxide (HTO) and organically-bound tritium (OBT) from these studies are shown in Table 5.7.4-12.



CLIENT
CANADIAN NUCLEAR LABORATORIES

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT

TITLE
PERCH LAKE SEDIMENT SAMPLING LOCATIONS

CONSULTANT

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	MM
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0012	0.0	5.7.4-12

REFERENCE(S)
1. BASEMAP PROVIDED BY CNL

Table 5.7.4-12: Perch Lake Sediment Sampling Results

Site	Year 2003		Year 2013	
	HTO (Bq/L)	OBT (Bq/L)	HTO (Bq/L)	OBT (Bq/L)
PL1	3,960 ± 75	1,995 ± 88	1,706 ± 13	691 ± 18
PL2	12,550 ± 250	2,970 ± 149	1,729 ± 17	741 ± 15
PL3	1,320 ± 26	490 ± 25	1,579 ± 16	952 ± 38

Source: CNL 2016c

Bq/L = Becquerels per litre; HTO = tritium oxide; OBT = organically-bound tritium.

Additionally, concentrations of Sr-90, Cs-137, and Co-60 in Perch Lake sediments have been reported in the CRL ERA (CNL 2014c). Concentrations of Sr-90 in Perch Lake sediment ranged from 845 Bq/kg to a maximum of 4,290 Bq/kg dry weight. Concentrations of Cs-137 in Perch Lake sediment ranged from 63.4 Bq/kg to a maximum of 355 Bq/kg dry weight. Concentrations of Co-60 in Perch Lake sediment ranged from 124 Bq/kg to a maximum of 296 Bq/kg dry weight.

Beach sand is routinely monitored at locations on the Ottawa River, including four upstream reference locations, two locations at the CRL property downstream boundary (both near Pointe au Baptême), and five locations farther downstream of the CRL property. The upstream locations are used to establish background concentrations of radionuclides. The CRL property boundary locations are considered to represent the RSA. Concentrations of Cs-137 are slightly elevated at the CRL property boundary, with annual averages ranging from 18.1 to 33.4 Bq/kg from 2011 to 2015. Sediment monitoring locations farther downstream of the CRL property are considered to be representative of the area beyond the RSA. Sediment monitoring results averaged for upstream, property boundary, and downstream locations from 2011 to 2015 are shown in Table 5.7.4-13.

Table 5.7.4-13: Average Radionuclide Concentrations in Ottawa River Sediment (Bq/kg dry weight)

	2011	2012	2013	2014	2015	Average
Reference locations (Upstream)						
Cesium-134	<0.22	<0.25	<0.27	<0.23	<0.25	<0.24
Cesium-137	3.3	3.6	3.1	4.7	3.7	3.7
Cobalt-60	<0.21	<0.25	<0.3	<0.3	<0.3	<0.27
Potassium-40	563	649	672	790	616	658
Regional Study Area (CRL Property Boundary)						
Cesium-134	<0.3	<0.23	<0.3	<0.27	<0.24	<0.27
Cesium-137	33.4	33.4	29.9	29.8	18.1	28.9
Cobalt-60	<0.4	0.46	<0.4	<0.3	<0.3	<0.37
Potassium-40	734	771	745	594	701	709
Beyond Regional Study Area (Downstream Locations)						
Cesium-134	<0.23	<0.23	<0.26	<0.26	<0.26	<0.25
Cesium-137	6.1	6.1	6.2	6.7	6.6	6.3
Cobalt-60	<0.25	<0.24	<0.3	<0.3	<0.3	<0.28
Potassium-40	747	757	805	759	894	792

Source: CNL 2016c

<= indicates results below the detection level, or an average calculated using one or more results below detection level.

Bq/kg = Becquerels per kilogram.

5.7.4.9 Radioactivity in Fish

Fish are collected annually from upstream and downstream locations on the Ottawa River, and from Chalk Lake. There are no fish habitats located in the SSA. Fish have periodically been sampled from Perch Lake. Studies conducted in 2003 and 2013 included measurements of HTO in water as well as HTO and OBT in fish and clams (CNL ETB 2016). The results of these studies are shown in Figure 5.7.4-13 and Figure 5.7.4-14. Tritium oxide concentrations in water are less than the maximum acceptable concentration of 7,000 Bq/L specified for drinking water (Health Canada 2017). Based on a water content of 75% by mass (CSA 2014) and an internal dose conversion coefficient of 1.38×10^{-4} micrograys per day per Becquerel's per kilogram (µGy/d)/(Bq/kg) as presented in the ERA (CNL 2014c), the concentrations of tritium in fish and clams are significantly less than concentrations that would result in doses exceeding the benchmark of 400 µGy/h for aquatic biota.

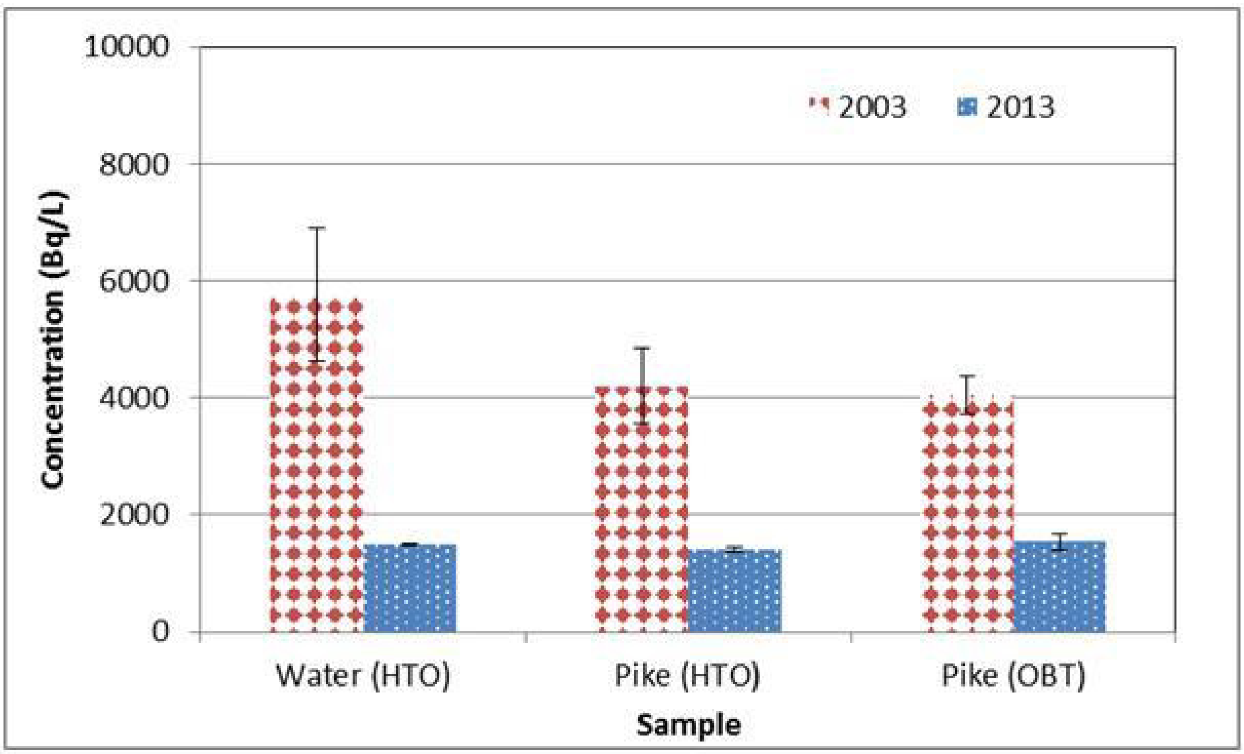


Figure 5.7.4-13: Tritium Oxide Activity Concentrations of Water, and Tritium Oxide and Organically Bound Tritium Activity Concentrations of Pike Sampled in June of 2003 and 2013

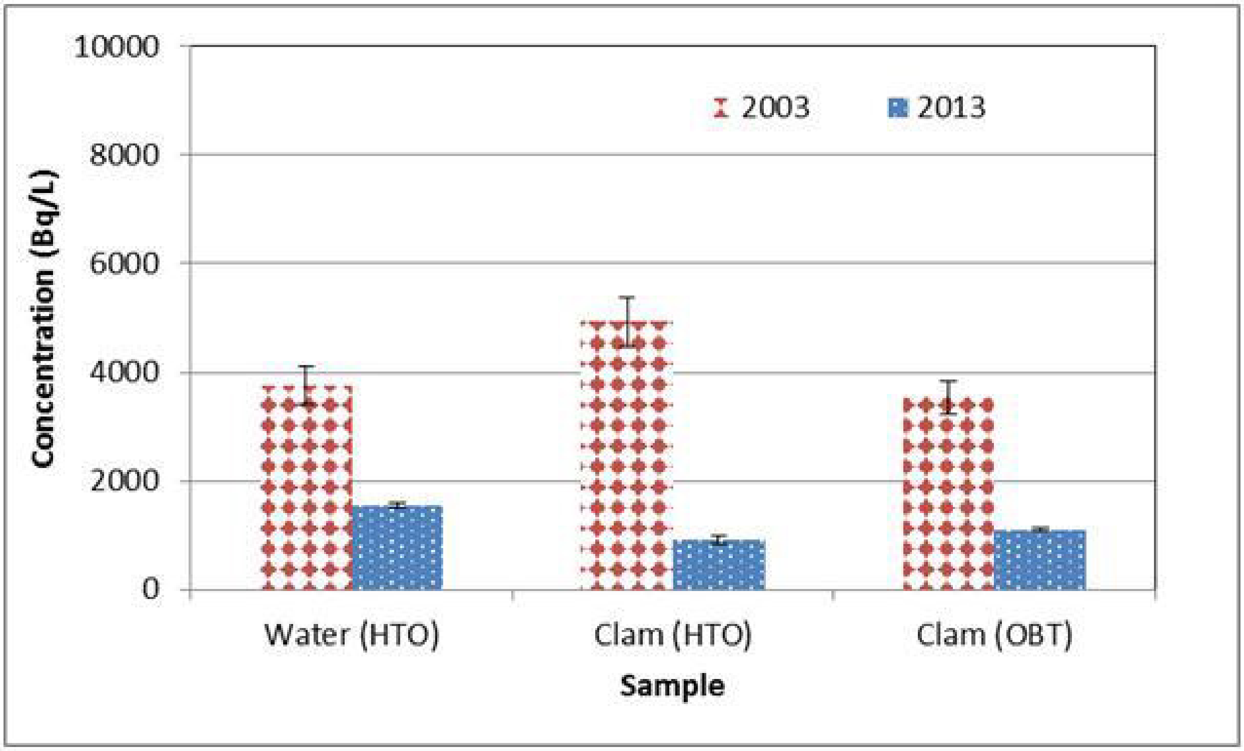


Figure 5.7.4-14: Tritium Oxide Activity Concentrations of Water, and Tritium Oxide and Organically Bound Tritium Activity Concentrations of Clams Sampled in June of 2003 and 2013

Fish is sampled from Chalk Lake, which is partly within the CRL property boundary and is therefore considered to be representative of the RSA. While this location is within the CRL property boundary, it is not expected to be affected by the NSDF Project, since the NSDF will not drain to the Maskinonge lake basin, which contains Chalk Lake. Radioactivity in fish at these locations is displayed in Table 5.7.4-14. Elevated tritium concentrations have been measured in fish from Chalk Lake. Average concentrations in 2015 of HTO and OBT in Chalk Lake fish were 38 Bq/kg and 25 Bq/kg respectively. For comparison, in 2015 Ottawa River fish upstream of CRL at Mackey had concentrations of less than 2 Bq/kg and less than 2.9 Bq/kg for HTO and OBT.

Table 5.7.4-14: Radioactivity (Bq/kg fresh weight) in Fish Sampled from Chalk Lake

	2011	2012	2013	2014	2015	2011-2015 Average
Chalk (Sturgeon) Lake						
Carbon-14	273	297	275	303	278	285
Cesium-134	<0.13	0.16	<0.17	<0.14	<0.19	<0.16
Cesium-137	10.8	10	9.7	8.3	15.3	10.8
Tritium	NA	NA	32.6	33	38	34.5
Organically Bound Tritium	NA	NA	25.2	26	24.5	25.2
Gross Alpha	<0.23	<0.21	0.42	0.22	<0.18	<0.25
Gross Beta	148	116	171	144	159	148
Potassium-40	140	143	209	147	151	158

Source: CNL 2016c.
<= indicates results below the detection level, or an average calculated using one or more results below detection level.
Bq/kg = Becquerels per kilogram.
N/D = indicates results below the critical level (i.e., not detected).
N/A = not available.

Fish are sampled from one upstream location and two downstream locations in the Ottawa River. Radioactivity in fish from downstream locations could potentially be affected by the NSDF Project site via discharge from the Perch Lake basin to the Ottawa River. The RSA fish monitoring results are displayed in Table 5.7.4-15.

Table 5.7.4-15: Radioactivity (Bq/kg fresh weight) in Fish Sampled from the Ottawa River

	2011	2012	2013	2014	2015	2011-2015 Average
Highview, 9 km downstream of CRL						
Carbon-14	226	253	258	372	260	274
Cesium-134	<0.12	<0.23	<0.14	<0.14	<0.12	<0.15
Cesium-137	9.4	10	9.2	18.5	52.8	19.98
Tritium	N/A	N/A	6.4	8.4	4	6.3
Organically Bound Tritium	N/A	N/A	17.9	2.9	8.6	9.8
Gross Alpha	0.41	<0.37	<0.26	ND	<0.9	<0.48
Gross Beta	153	150	143	131	171	149.6
Potassium-40	111	161	165	149	150	147
Waltham, 42 km downstream						
Carbon-14	244	248	272	254	236	250.8
Cesium-134	<0.15	<0.16	<0.14	<0.15	<0.14	<0.15
Cesium-137	13.3	7.2	8.3	8.3	26.7	12.8
Tritium	N/A	N/A	3.3	12	6	7.1
Organically Bound Tritium	N/A	N/A	14.3	2.7	8.3	8.4
Gross Alpha	<0.26	0.4	<0.45	ND	<0.15	<0.31
Gross Beta	142	145	152	143	159	148
Potassium-40	116	163	150	150	175	151

Table 5.7.4-15: Radioactivity (Bq/kg fresh weight) in Fish Sampled from the Ottawa River

	2011	2012	2013	2014	2015	2011-2015 Average
Ottawa River at Mackey, 28 km Upstream						
Carbon-14	227	254	254	267	260	252
Cesium-134	<0.13	<0.12	<0.12	<0.14	<0.31	<0.16
Cesium-137	7.8	7	7	8.5	6.3	7.3
Tritium	N/A	N/A	N/A	5.3	<2	3.6
Organically Bound Tritium	N/A	N/A	N/A	1.1	<2.9	2.0
Gross Alpha	0.31	<0.2	<0.2	<0.02	<1.88	<0.52
Gross Beta	150	137	137	154	142	144
Potassium-40	127	151	151	163	144	147.2

Source: CNL 2016c
<= indicates results below the detection level, or an average calculated using one or more results below detection level.
Bq/kg = Becquerels per kilogram.
N/D = indicates results below the critical level (i.e., not detected).
N/A = not available.

The CRL Environmental Risk Assessment included estimates of radiation dose to fish at various locations on the CRL site, including East Swamp, West Swamp, Perch Lake, and Perch Creek. The average and maximum radiation dose calculated for fish present in these locations is shown in Table 5.7.4-16 (CNL 2014c).

Table 5.7.4-16: Dose to fish in East Swamp, Perch Creek, and Perch Lake

Receptor	Mean Combined Dose (µGy/hr)	Maximum Combined Dose (µGy/hr)
East Swamp		
Red-belly Dace	17.0	55.13
West Swamp		
Red-belly Dace	16.0	45.25
Perch Lake		
Pumpkinseed	2.92	3.51
Brown Bullhead	2.93	3.53
Perch Lake Inlet 1		
Red-belly Dace	9.21	18.3
Perch Lake Inlet 2		
Red-belly Dace	1.92	3.51
Perch Creek		
Creek Chub	1.26	1.58

5.7.4.10 Radioactivity in Terrestrial Foodstuffs

5.7.4.10.1 Terrestrial Animals

No monitoring of terrestrial animals is performed specifically within the SSA or LSA. Radioactivity in large game animals (e.g., deer) is measured when animals are hunted or killed accidentally in the vicinity of the CRL property. Samples obtained from within 25 km are considered to be representative of the RSA. The concentration of radioactivity in the flesh and bones of terrestrial animals are shown in Table 5.7.4-17 and Table 5.7.4-18, respectively.

Historically, elevated levels of radioactivity have been measured in large game animals from within 25 km of the CRL property (e.g., approximately 1,100 Bq/L tritium in large game animal flesh sample in 2001). This is related to historical contamination of the CRL WMAs (CNL 2016c). Fences installed in 2004 to prevent game animal access to areas with surface contamination have led to a reduction in radioactivity in local game animals. The average tritium concentrations in the flesh of large game animals collected within 25 km of the CRL property from 2011 to 2015 have ranged from 11 to 88 Bq/kg. Average gross beta activity ranged from 111 to 313 Bq/kg, where naturally-occurring K-40 was the primary contributor (Table 5.7.4-17 and Table 5.7.4-18). Tritium concentrations in the flesh of large game animals collected beyond 50 km of the CRL property from 2011 to 2015 have ranged from 1 to 11 Bq/kg.

Table 5.7.4-17: Radioactivity in Flesh of Large Game Animals (Bq/kg fresh weight)

	2011	2012	2013	2014	2015	2011-2015 Average
Regional Study Area (Game animals within 25 km)						
Tritium	60	64	30	11	88	50.6
Organically Bound Tritium	14.5	50	13.8	3.3	56	27.5
Gross Beta	131	132	125	111	313	162.4
Gross Alpha	<0.3	0.63	0.3	<0.5	<0.4	<0.43
Total Strontium	1.2	2	<0.1	N/D	N/D	<1.1
Potassium-40	105	163	108	87	228	138
Cobalt-60	<0.2	<0.2	<0.2	<0.2	<0.4	<0.24
Cesium-134	<0.1	<0.2	<0.1	<0.2	<0.3	<0.18
Cesium-137	14.1	18.7	16.7	8.4	62	23.98

Source: CNL 2016c.
Values reported for each year represent the average radionuclide concentrations measured from multiple animals. The “average” column indicates the average of these annual values (not weighted by number of samples).
<= indicates results below the detection level, or an average calculated using one or more results below detection level.
Bq/kg = Becquerels per kilogram.
N/D = indicates results below the critical level (i.e., not detected).
N/A = not available

Table 5.7.4-18: Radioactivity in Bones of Large Game Animals (Bq/kg fresh weight)

	2011	2012	2013	2014	2015	2011-2015 Average
Regional Study Area (Game animals within 25 km)						
Gross Beta	423	2,214	1,329	251	798	1,003
Gross Alpha	27	37	17	112	36	45.8
Total Strontium	60	396	241	38	36	154.2
Potassium-40	21	36	33	162	57	61.8
Cobalt-60	<2.1	<1.8	<1.4	<1.8	<1.8	<1.78
Cesium-134	<2.3	<1.9	<1.4	<1.8	<1.7	<1.82
Cesium-137	<2.1	2.1	3.3	2	<4	<2.7

Source: CNL 2016c.

Values reported for each year represent the average radionuclide concentrations measured from multiple animals. The “average” column indicates the average of these annual values (not weighted by number of samples).

<= indicates results below the detection level, or an average calculated using one or more results below detection level.

Bq/kg = Becquerels per kilogram.

N/A = not available.

The dose to large mammals was estimated in the CRL ERA (CNL 2014c), based on measured radionuclide concentrations in flesh and bone from animals accidentally killed on CRL property, and modelled concentrations of radionuclides in air. The dose to deer from radionuclides in tissue and Ar-41 in air was estimated to range from 0.038 to 0.064 µGy/hr. The estimated total dose to eastern wolf is similar and considerably less than the benchmark of 100 µGy/hr.

5.7.4.10.2 Terrestrial Plants

Garden produce is sampled annually from gardens and farmers markets at off-site population centres. Additionally, garden produce is sampled from Killaloe, 55 km south of the NSDF Project site, to evaluate background radioactivity. Samples are collected annually and analyzed for tritium (free tritium is shown in Table 5.7.4-19 and organically bound tritium (OBT) in Table 5.7.4-20), gross beta (Table 5.7.4-21), gross alpha (Table 5.7.4-22), and Cs-137 (Table 5.7.4-23). Results are grouped into fruit, root, or vegetable categories. The Chalk River and Balmer Bay sampling locations are within the RSA, while remaining locations are beyond the RSA.

No produce is grown for human consumption at the NSDF Project site or within the CRL property boundary. It is noted that the NSDF site will be subject to vegetation management procedures, such that no vegetation that could penetrate waste will be allowed to grow.

At the reference location (Killaloe), free water tritium concentrations in produce have averaged less than 3 Bq/kg. This is comparable to reference measurements from across Ontario, which range from 1 to 6 Bq/kg (OPG 2013). Elevated tritium concentrations were measured at the locations closest to the CRL property. At Balmer Bay, tritium concentrations in all produce from 2011 to 2015 have averaged 18 Bq/kg, with an average of 24.2 Bq/kg in vegetable produce (Table 5.7.4-19). At Deep River, tritium concentrations in all produce from 2011 to 2015 have averaged 12 Bq/kg. Additionally, elevated tritium concentrations have been measured at Pembroke, but this is likely associated with a local non-CNL industry in the area.

Gamma spectroscopy has demonstrated that the majority of gross beta activity is due to naturally-occurring Potassium-40 (K-40). Gross beta results are highly variable due to the variability in naturally-occurring radionuclides at the monitoring locations. Low level gross alpha activity was detected in produce samples from all areas, including the reference area. Naturally occurring alpha emitters likely account for the observed alpha activity. The Cs-137 measurements in garden produce are frequently below the detection level. Some low level (approximately 0.5 Bq/kg) Cs-137 concentrations have been detected in local produce. Cs-137 is not solely attributable to CRL operations as it is present in the environment from atmospheric fallout from global weapons tests and the Chernobyl nuclear accident.

In addition to monitoring of garden produce as part of the environmental monitoring program, surveys of contamination resulting from groundwater plumes at CRL have included sampling and analysis of vegetation. Radiological surveying conducted at the East Swamp is particularly relevant to the NSDF, as it is immediately west of the NSDF site and may be impacted by NSDF operations. Contamination exists in the East Swamp as a result of groundwater plumes from the Chemical Pit and Reactor Pit 2. Vegetation sampling was conducted in the East Swamp during 2002, 2007, and 2012 surveys. These surveys included measuring contamination of tree surfaces, leaves/ferns (in 2002), tree cores/branches (in 2012), and surface vegetation (in 2012).

Tree surface contamination was measured with a Ludlum 44-9 pancake Geiger-Mueller detector, which responds to alpha, beta, and gamma radiation, and was used with the detector in contact with the trunk, approximately 1 m off the ground. Tree surface contamination results from 2012 are shown in Figure 5.7.4-15.

Total beta activities in tree leaves surveyed in 2002 were on average 1.25 times higher than beta activity in soil (see East Swamp soil monitoring results in Section 5.7.4.7 Radioactivity in Soil). Alpha activity in tree leaves and ferns at the East Swamp background location were 7 and 13 Bq/kg dry weight, respectively. Throughout East Swamp, alpha activity in tree leaves average 10 Bq/kg, with a maximum of 24 Bq/kg. Activity in ferns was slightly higher, with average values of 15 and a maximum of 47 Bq/kg. These results are considered to be very close to background, indicating negligible alpha emitter uptake into vegetation. Cesium-137 concentrations were generally greater in vegetation than in soil at East Swamp, with an average factor of 4.9 times higher for ferns, and 1.2 times higher for trees. Cobalt-60 concentrations in vegetation were a small fraction of that in soil.

In 2012, total beta activity in vegetation was on average 1.2 times higher than that in soil, with ratios ranging from 0.17 to 6.2 more beta activity in vegetation than corresponding soil samples. Gross alpha activity in vegetation was at or near background levels of 13 Bq/kg, with the exception of vegetation from the Chemical Pit groundwater discharge zone where levels were elevated (260 Bq/kg). Cesium-137 concentrations ranged from background to a maximum of 11,400 Bq/kg. Cobalt-60 concentrations in vegetation were a small fraction of that observed in soil.

Table 5.7.4-19: Free Tritium in Plant Produce (Bq/kg fresh weight)

	2011	2012	2013	2014	2015	2011-2015 Average
Fruit						
Killaloe	<3	<3	N/D	<2	N/D	<2.7
Pembroke	N/A	16	108	18	10	38
Balmer Bay	11	14	24	25	N/A	18.5
Deep River	9	4	9	26	12	12.0
Chalk River	7	N/A	5	10	6	7
Petawawa	7	<3	3	<3	<3	<3.8
Sheenboro	7	5	3	5	3	4.6
Root						
Killaloe	<3	<3	N/D	N/D	<4	<3.3
Pembroke	18	6	39	10	7	16
Balmer Bay	12	4	15	11	N/A	10.5
Deep River	9	12	9	12	17	11.8
Chalk River	5	4	3	<2	<3	<3.4
Petawawa	3	3	3	<3	N/A	<3
Sheenboro	<3	<3	2	3	<2	<2.6
Vegetable						
Killaloe	<3	<3	N/D	N/D	<3.4	<3.1
Pembroke	15	12	10	16	14	13.4
Balmer Bay	40	26	15	24	16	24.2
Deep River	6	17	5	23	16	13.4
Chalk River	9	<5	4	4	5	<5.4
Petawawa	<3	7	6	8	N/D	<6.0
Sheenboro	12	<4	5	<3	4	<5.6

Source: CNL 2016c.

<= indicates results below the detection level, or an average calculated using one or more results below detection level.

Bq/kg = Becquerels per kilogram.

N/A = not available.

N/D = indicates results below the critical level (i.e., not detected).

Table 5.7.4-20: Organically Bound Tritium in Plant Produce (Bq/kg fresh weight)

	2011	2012	2013	2014	2015	2011-2015 Average
Fruit						
Killaloe	0.1	0.6	0.1	N/D	<2.1	<0.33
Pembroke	N/A	0.6	2.2	0.8	8.9	1.20
Balmer Bay	0.3	N/A	0.4	1.2	N/A	0.68
Deep River	N/A	0.4	0.2	0.6	9.3	0.40
Chalk River	0.2	N/A	0.3	1.87	<2	<0.69
Petawawa	0.2	0.4	0.2	<0.1	<2.8	<0.26
Sheenboro	0.2	0.3	1	0.4	2.6	0.42
Root						
Killaloe	0.8	1.8	0.4	<0.4	11	<2.45
Pembroke	N/A	9.2	2.6	1.1	8.9	5.45
Balmer Bay	0.7	3.2	2.1	1.5	NA	1.84
Deep River	N/A	3	2	1.4	6.6	3.25
Chalk River	0.2	0.5	1	1	3.3	1.08
Petawawa	0.7	1.3	1.6	0.1	N/A	0.88
Sheenboro	0.5	1.1	2.4	2.1	3	1.58
Vegetable						
Killaloe	0.4	0.4	0.4	<0.3	12	<2.30
Pembroke	N/A	6.6	1.8	8.7	41	14.5
Balmer Bay	0.9	1.3	1.1	7.7	6.2	3.1
Deep River	N/A	0.6	0.5	0.6	3.3	1.3
Chalk River	0.9	0.8	1.7	0.6	4	1.6
Petawawa	1	0.2	0.7	0.8	<1.7	<1.0
Sheenboro	0.5	1.1	0.6	0.9	2.6	1.1

Source: CNL 2016c.
Bq/kg = Becquerels per kilogram.
'<' = indicates results below the detection level, or an average calculated using one or more results below detection level.
N/D = indicates results below the critical level (i.e., not detected).
N/A = not available.

Table 5.7.4-21: Gross Beta Activity in Plant Produce (Bq/kg fresh weight)

	2011	2012	2013	2014	2015	2011-2015 Average
Fruit						
Killaloe	71	61	36	109	68	69.0
Pembroke	N/A	159	116	50	79	101.0
Balmer Bay	76	50	60	110	N/A	74.0
Deep River	96	62	7	114	121	80.0
Chalk River	92	N/A	94	104	91	95.3
Petawawa	93	85	68	91	261	119.6
Sheenboro	44	141	82	61	52	76
Root						
Killaloe	117	158	248	114	170	161.4
Pembroke	1223	105	206	163	148	369.0
Balmer Bay	130	216	134	119	N/A	149.8
Deep River	123	116	123	117	159	127.6
Chalk River	77	56	149	140	128	110.0
Petawawa	193	83	136	134	N/A	136.5
Sheenboro	109	59	44	102	94	81.6
Vegetable						
Killaloe	202	58	147	183	58	129.6
Pembroke	119	101	136	109	216	136.2
Balmer Bay	110	71	60	79	174	98.8
Deep River	81	135	103	104	97	104.0
Chalk River	102	76	72	98	148	99.2
Petawawa	148	56	122	124	124	114.8
Sheenboro	170	127	84	184	286	170.2

Source: CNL 2016c.
Bq/kg = Becquerels per kilogram;
km = kilometres.
N/A = not available.

Table 5.7.4-22: Gross Alpha Activity in Plant Produce (Bq/kg fresh weight)

	2011	2012	2013	2014	2015	2011-2015 Average
Fruit						
Killaloe	0.17	0.17	0.15	<0.74	N/D	<0.31
Pembroke	N/A	0.36	<0.23	0.74	0.2	<0.38
Balmer Bay	0.25	<0.16	0.2	N/D	N/A	<0.20
Deep River	0.23	<0.09	N/D	4.52	0.19	<1.26
Chalk River	0.13	N/A	0.4	N/D	0.18	<0.24
Petawawa	0.12	0.21	<0.19	N/D	0.1	<0.16
Sheenboro	0.09	0.29	0.22	N/D	0.81	<0.35
Root						
Killaloe	0.7	0.26	0.8	12.8	0.41	2.99
Pembroke	0.72	<0.17	<0.3	34.9	<0.49	<7.32
Balmer Bay	0.44	0.73	0.21	N/D	N/A	<0.46
Deep River	0.29	0.27	0.27	N/D	0.53	<0.34
Chalk River	0.63	0.26	1.02	1.13	0.21	0.65
Petawawa	<0.19	0.66	<0.13	N/D	N/A	<0.33
Sheenboro	0.21	0.32	0.25	30.8	0.24	6.36
Vegetable						
Killaloe	0.41	0.41	0.7	0.73	0.15	<0.48
Pembroke	0.41	0.31	0.57	N/D	1.33	<0.66
Balmer Bay	0.4	0.3	0.13	0.57	<1.17	<0.51
Deep River	0.24	0.49	0.32	0.3	1.03	0.48
Chalk River	0.31	0.3	0.34	0.34	0.5	0.36
Petawawa	0.26	0.16	0.43	<0.26	N/D	<0.28
Sheenboro	0.53	0.6	0.45	1.13	1.07	0.76

Source: CNL 2016c.

Bq/kg = Becquerels per kilogram.

'<' = indicates results below the detection level, or an average calculated using one or more results below detection level.

N/D = indicates results below the critical level (i.e., not detected).

N/A = not available.

Table 5.7.4-23: Cesium 137 in Plant Produce (Bq/kg fresh weight)

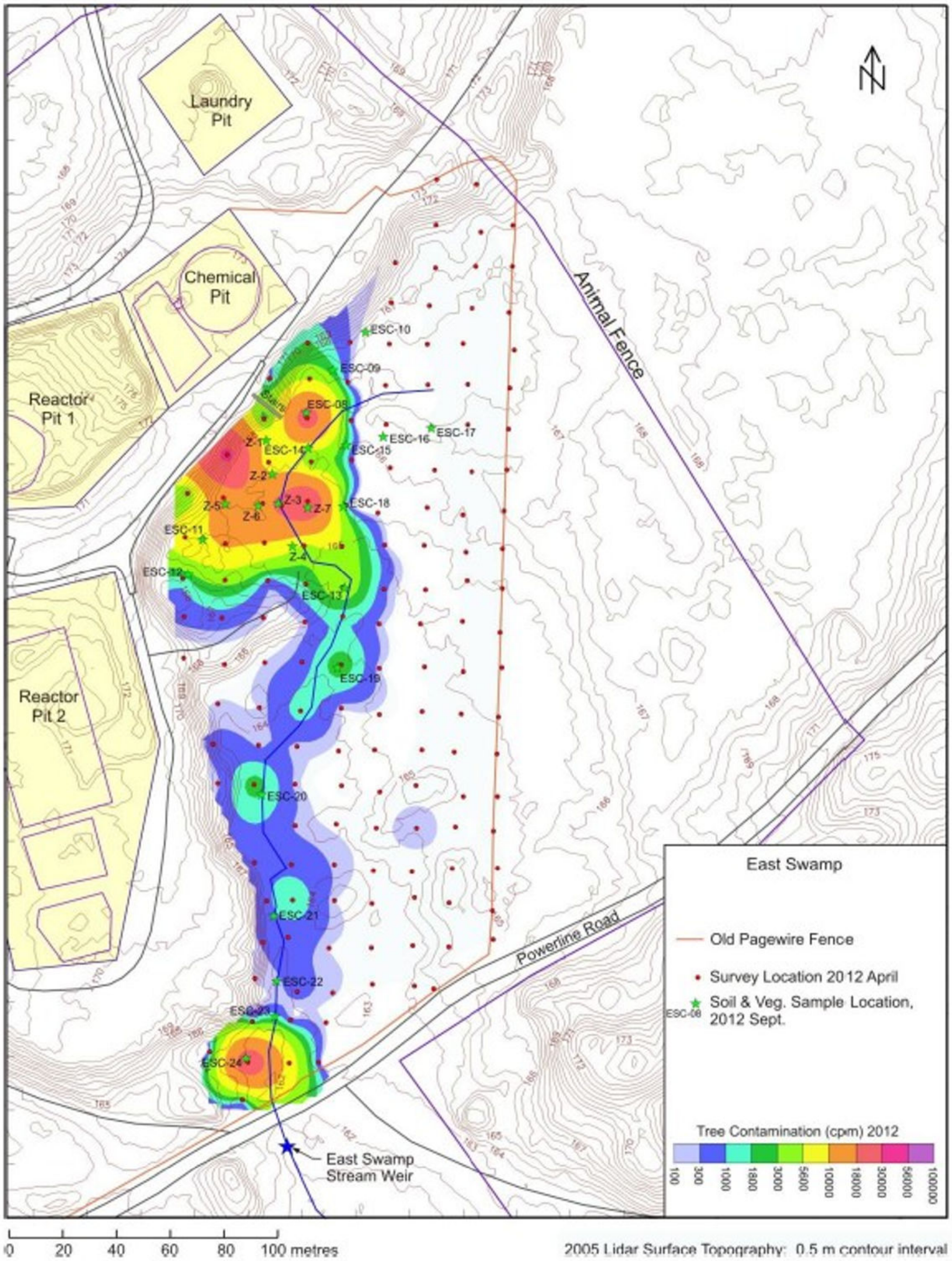
	2011	2012	2013	2014	2015	2011-2015 Average
Fruit						
Killaloe	<0.11	<0.13	<0.09	<0.09	<0.11	<0.11
Pembroke	N/A	<0.14	<0.1	<0.09	<0.13	<0.12
Balmer Bay	<0.09	<0.11	<0.09	<0.09	N/A	<0.10
Deep River	<0.16	<0.15	<0.13	<0.14	<0.12	<0.14
Chalk River	<0.12	N/A	<0.08	<0.13	<0.11	<0.11
Petawawa	<0.12	<0.13	<0.1	0.31	0.16	<0.16
Sheenboro	<0.15	<0.1	<0.24	<0.11	<0.11	<0.14
Root						
Killaloe	<0.1	<0.12	<0.17	<0.19	<0.1	<0.14
Pembroke	<0.14	<0.23	<0.11	<0.21	<0.1	<0.16
Balmer Bay	<0.14	<0.2	<0.16	0.53	N/A	<0.26
Deep River	<0.25	<0.11	0.13	<0.19	<0.11	<0.16
Chalk River	<0.21	<0.2	<0.12	<0.3	<0.11	<0.19
Petawawa	<0.28	0.21	0.16	0.51	N/A	<0.29
Sheenboro	<0.17	<0.09	<0.1	0.64	<0.1	<0.22
Vegetable						
Killaloe	<0.25	0.13	<0.15	<0.22	0.31	<0.21
Pembroke	<0.17	<0.6	<0.14	<0.13	<0.12	<0.23
Balmer Bay	<0.21	0.65	<0.09	<0.1	<0.19	<0.25
Deep River	<0.14	<0.16	<0.17	<0.16	<0.14	<0.15
Chalk River	0.44	<0.17	0.2	<0.26	<0.16	<0.25
Petawawa	<0.4	<0.12	<0.19	<0.13	<0.19	<0.21
Sheenboro	<0.28	<0.09	0.3	<0.27	0.46	<0.28

Source: CNL 2016c.

Bq/kg = Becquerels per kilogram.

<= indicates results below the detection level, or an average calculated using one or more results below detection level.

N/A = not available.



REFERENCE(S)
1. BASEMAP PROVIDED BY CNL

CLIENT
CANADIAN NUCLEAR LABORATORIES

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT

TITLE
VEGETATION CONTAMINATION IN THE EAST SWAMP IN 2012

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	MM
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0012	0.0	5.7.4-15

5.7.4.10.3 Milk

No milk production occurs within the SSA, LSA, or RSA. Milk is sampled monthly from a dairy in Pembroke, considered to be beyond the RSA. Samples are analyzed to quantify the concentration of tritium and other radionuclides. The average annual concentration of radionuclides in milk from the dairy in Pembroke is shown in Table 5.7.4-24.

The contaminants tritium, C-14, and Cs-137 are associated with CRL operations and were measured in milk samples at detectable levels. Tritium concentrations were comparable to the natural background range of 5 to 11 Bq/L (CNL 2016c, NCRP 1987). Local non-CNL industries in Pembroke may influence the measured tritium concentrations in milk samples. Concentrations of C-14 in milk samples have ranged from 15 to 17 Bq/L. This is comparable to the natural background level of 15 Bq/L (CNL 2016c, UNSCEAR 1993).

Concentrations of Cs-137 have remained at approximately 0.02 Bq/L from 2011 to 2015. This is comparable to the estimated background concentrations of Cs-137 in milk in Canada, which are estimated to range from 0.0017 Bq/L to 0.024 Bq/L due to atmospheric nuclear weapons testing and the Chernobyl nuclear accident (CNL 2016c, Health Canada 2001). Naturally occurring radionuclides such as K-40 were also detected in milk samples.

Table 5.7.4-24: Average Concentration of Radioactivity in Milk (Bq/L) from the Dairy in Pembroke

	2011	2012	2013	2014	2015	2011-2015 Average
Tritium	7	<3	2.8	2.4	<2.4	<3.5
Carbon-14	15	17	16.7	17	17	16.5
Cesium-137	0.023	0.02	0.021	0.02	0.012	0.019
Iodine-131	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Actinium-228	<0.06	<0.05	<0.07	<0.08	<0.05	<0.06
Potassium-40	60	47	55.1	59.1	66	57.4
Radium-226	<0.02	<0.02	<0.02	<0.03	<0.02	<0.022
Thorium-228	<0.03	<0.03	<0.04	<0.05	<0.04	<0.038

Source: CNL 2016c.

<= indicates results below the detection level, or an average calculated using one or more results below detection level.

Bq/L = Becquerels per litre.

5.7.5 Project Interactions and Mitigation

5.7.5.1 Methods

This section describes the process by which interactions between NSDF Project components and activities and ecological health were identified and evaluated. Potential effect pathways are identified and mitigation developed to eliminate and/or reduce effects is presented. A pathways analysis is then used to focus the assessment on key interactions between the NSDF Project and the environment by evaluating the different effect pathways to determine if, after incorporation of mitigation, there is still potential to cause residual effects. Where effects will be adequately mitigated and are not forwarded for further analysis (i.e., secondary pathways, or where mitigation will remove the pathway altogether), the reasons for concluding the assessment at this stage are articulated. Primary pathways that may lead to residual effects after incorporation of mitigation are further characterized in subsequent subsections of the assessment. As such, this section helps to focus the remainder of the assessment on those interactions (effects pathways) with the potential to result in residual adverse effects.

The first part of the analysis was to identify the potential effects pathways for all stages of the NSDF Project. The next step in the analysis was the development of environmental design features and mitigation that could be incorporated into the NSDF Project to eliminate and/or reduce adverse effects to non-human biota. Environmental design features included project design elements, environmental best practices, and management policies and procedures. Environmental design features and mitigation were developed through an iterative process between the NSDF Project's engineering and environmental teams, combined with input from project-specific or regional engagement with other interested parties. The design features and/or mitigation were selected considering their effectiveness for implementation and maintenance, and their appropriateness within the context of the identified effect pathways.

After incorporation of mitigation, potential pathways were evaluated into the following categories using scientific knowledge, logic, experience with similar developments, and the effectiveness of environmental design features and mitigation:

- **No pathway –** pathway is removed by environmental design features or mitigation such that the NSDF Project would not be expected to result in a measurable environmental change relative to Base Case values and therefore would have no residual effects to non-human biota.
- **Secondary pathway –** the pathway could result in a measurable minor environmental change, but would have a negligible residual effect to non-human biota relative to guideline values and is not expected to contribute cumulatively to other NSDF Project effects or to the effects of other past, present or reasonably foreseeable developments to cause a significant effect.
- **Primary pathway –** the pathway is likely to result in an environmental change relative to the guideline values that could contribute to residual effects to non-human biota.

Environmental design features and mitigation that have been or could be incorporated into the NSDF Project to eliminate and/or reduce adverse effects were considered. Potential pathways that were completely removed due to implementation of environmental design or mitigation were not assessed further. Pathways that were assessed to be secondary and demonstrated to have a negligible residual effect to non-human biota through simple qualitative or semi-quantitative evaluation of the pathway were also not advanced for further assessment.

Primary pathways were carried forward for more detailed quantitative and qualitative effects analysis to characterize the residual effects of the NSDF Project and the NSDF Project in combination with other past, present and reasonably foreseeable developments.

5.7.5.2 Results

Pathways through which all stages of the NSDF Project may interact with and result in changes to measurement indicators for ecological health is provided in Table 5.7.5-1.

Table 5.7.5-1: Pathways Analysis for Ecological Health Valued Components

Project Activity	Effects Pathways	Management Practices and Mitigation Actions	Pathway Assessment
■ Project activities during the operations and closure phase: ▪ Surface water management ▪ Operation of the WWTP ▪ Discharge of treated effluent from the WWTP	■ Release of emissions from the ECM from radioactive dust created during handling of bulk materials and emissions of gases during storage and disposal of radioactive materials. ■ Release of emissions from the WWTP to air during operations and closure.	■ Implementation of CNL's Procedure for Management and Monitoring of Emissions, which includes operational control monitoring and verification monitoring. ■ The Dust Management Plan for the NSDF Project will be developed and will include: ▪ restricting or suspending activities if unacceptable amounts of dust are generated due to winds or other site conditions; ▪ use of water spraying or misting techniques (e.g., water trucks) as the primary dust control method; ▪ use of fixatives (e.g., chemical suppressant) for dust control during winter season or shutdown periods, and for use as daily/interim cover; ▪ suspension of excavating, loading, hauling, and dumping operations when wind speeds exceed the specified criterion; and ▪ vehicles that have come into contact with contamination will be required to pass through the vehicle decontamination facility ■ Processed leachate will not be heated within the WWTP ■ There is active ventilation within the WWTP building and all emissions to air will be filtered prior to release.	Primary
	Discharge of treated effluent from the WWTP to the East Swamp Wetland can cause changes to groundwater quality in the wetland and downstream surface water quality, which can affect ecological health.	■ The strategy for wastewater treatment is based on optimizing public and environmental protection by defining an approach to wastewater treatment that uses best demonstrated available technology that is economically achievable (BDATEA), and capable of meeting regulatory requirements. ■ The treatment target for effluent is the CRL Acceptability Criteria for Routine and Non Routine Discharge of Liquids to Stormwaters. ■ Treated effluent will be sampled and confirmed that it meets treatment targets before release to East Swamp Wetland ■ Discharge of treated effluent to the exfiltration gallery area will help to reduce water loss from the hydrogeological system.	Primary
	Leakage of leachate from the ECM during operations and closure may cause changes to groundwater quality in the wetland and downstream surface water quality, which can affect ecological health.	■ Design of the ECM includes base contours that have been developed using a herringbone pattern with ridges and valleys to promote leachate transport to the leachate collection system for removal. ■ The base liner design includes both primary and secondary liner systems that are designed to have redundancy in case of premature failure and are a combination of natural and synthetic barrier systems. ■ The HDPE geomembrane for the liner was selected as it is compatible with the leachate generated by the waste and will achieve a long service life. ■ The base liner system includes an underlying compacted clay liner to supplement the primary and secondary liner system. ■ The leachate collection system design provides access points for inspections, maintenance, repairs and replacements.	No Linkage
■ Project activities during the post-closure phase: ▪ On-going long-term performance monitoring, transfer of NSDF Project into the Post-Institutional Control Period	Release of emissions of gases from the radioactive waste in the post-closure phase.	■ A passive landfill gas monitoring venting system will be constructed contemporaneously with installation of the ECM final cover system. ■ The landfill gas monitoring probes will also be installed around the perimeter of the ECM to detect evidence of potential landfill gas migration away from the ECM.	Primary
	Leakage of leachate from the ECM during the post-closure phase (i.e., after Year 2400) from liner and cover failure as a result of normal evolution can cause changes to groundwater quality in the wetland and downstream surface water quality, which can affect ecological health.	■ The final cover system will be constructed to promote the shedding of surface water to mitigate infiltration into the mound, and minimize leachate generation. ■ The cover system design incorporates a series of shallow, trapezoidal, riprap-lined drainage channels that are designed to convey water at low velocity. ■ The perimeter road ditch will route the runoff around the ECM perimeter to minimize ponding of water into the closed ECM, erosion of the cover and underlying waste materials, destabilization of the ECM structure, and damage to access roads. ■ The ECM final grading and drainage plan includes collection ditches along the top of the ECM berm road to collect side slope drainage. ■ Environmental monitoring will be completed throughout the post-closure phase for the NSDF Project to confirm that the cover is functioning as intended.	Primary

This page intentionally left blank

5.7.5.3 No Linkage Pathways

The following pathway was assessed as having no measurable environmental change and hence, no linkage to residual effects on ecological health VCs.

- **Leakage of leachate from the ECM during operations and closure may cause changes to groundwater quality in the wetland and downstream surface water quality, which can affect ecological health.**

Design of the ECM includes base contours that have been developed using a herringbone pattern with ridges and valleys to promote leachate transport to the leachate collection system for removal. The base liner design include both primary and secondary liner systems that are designed to have redundancy in case of premature failure and are a combination of natural and synthetic barrier systems. The primary liner will include a leachate collection system with the secondary liner housing a leak detection system. The composite base liner will contain perforated HDPE collection and monitoring pipes. The HDPE geomembrane was selected as it is compatible with the leachate generated by the waste and is expected to perform as an effective hydraulic and diffusion barrier over the 500-year design life (Section 3.5.2.4). The base liner system will include an underlying compacted clay liner to supplement the primary and secondary liner system. The leachate collection and monitoring system design will provide accessible access points for monitoring, inspections, maintenance, repairs and replacements.

The primary liner system will contain the leachate collection system, and will convey leachate to a single collection point for removal from the mound, and ultimately to the WWTP for treatment. The primary liner system will also protect the natural environment below the mound from leachate migration, and will maintain a maximum depth of leachate on the geomembrane liner of less than or equal to 300 mm. The secondary liner system will contain the leak detection system, which will be used to detect leaks in the unlikely event that the primary liner system fails. The secondary liner will also protect the natural environment from leachate migration if the primary liner system fails. Leachate collected by the leachate collection system will be pumped to the onsite WWTP for treatment.

Designed berms consist of three main geotechnical elements, or layers, each contributing to the soundness and integrity of the berm itself and the whole ECM. A Slope Stability Analysis was completed to provide the information needed to support the design of the base slopes, sidewalls, and side slopes of the ECM. The Slope Stability Analysis addresses the range of anticipated loading conditions, under both short-term and long-term scenarios, to confirm that the slope designs will satisfy minimum factor-of-safety requirements for stability. Size and shape of the berms and each of the elements and layers were determined using a seismic design basis.

The implementation of these mitigation measures will reduce the potential for changes to groundwater and surface water quality from the NSDF site. As such, this pathway was determined to have no linkage to effects on the abundance of wildlife habitat, and survival and reproduction of wildlife and is not anticipated to affect the maintenance of self-sustaining and ecologically effective wildlife populations that overlap the RSA.

5.7.5.4 Secondary Pathways

No secondary pathways were identified as having residual effect on ecological health.

5.7.5.5 Primary Pathways

Primary pathways identified for ecological health and that are evaluted in the residual effects analysis (Section 5.7.6 Residual Effects Analysis) include:

- Release of emissions from the ECM from radioactive dust created during handling of bulk materials and emissions of gases during disposal of radioactive waste.
- Discharge of treated effluent from the WWTP to the East Swamp Wetland can cause changes to groundwater quality in the wetland and downstream surface water quality, which can affect ecological health.
- Release of gases during disposal of radioactive waste in the post-closure phase.
- Leakage of leachate from the ECM during the post-closure phase (i.e., after Year 2400) from liner and cover failure as a result of normal evolution can cause changes to groundwater quality in the wetland and downstream surface water quality, which can affect ecological health.

5.7.6 Residual Effects Analysis

5.7.6.1 Application Case Methods

This section describes the specific methods used to assess the residual effects on ecological health for the NSDF Project activities and pathways identified as primary in Table 5.7.5-1. Policies, guidelines and standards considered in the analysis, as well as the model used to predict residual effects are described.

Radiological dose to non-human biota may result from waterborne or airborne emissions from the NSDF Project. Dose to non-human biota from waterborne emissions is calculated during the operations phase, as well as during the post-Institutional control period (i.e., after 2400) of the post-closure phase for the NSDF Project. It is assumed that during the Institutional Control period (year 2100 to year 2400), the ECM liner and cover will be functional and no leachate will seep through the ECM liner.

Dose to non-human biota from airborne emissions is calculated only for the operations phase of the NSDF. This represents the bounding case, since it is expected that doses to non-human biota during the post-closure phase would be less than the operations phase due to the installation of the final cover.

5.7.6.1.1 Contaminants

Table 5.7.6-1 displays the bounding estimate of radionuclide inventory in the ECM, which was used in the assessment of dose to ecological receptors (CNL 2016d). This represents a bounding estimate of the ECM inventory for the total waste volume of the completed ECM (1,000,000 cubic metres [m^3]) used for assessment purposes. The inventory is a reference inventory based on the existing characterized waste streams, which form a small portion of the inventory. This was extrapolated to 1,000,000 m^3 using expert opinion. While there is uncertainty with this data set, the waste quality and characterization program will assure the inventory envelope is not exceeded.

Table 5.7.6-1: Bounding NSDF Project Waste Radionuclide Inventory to be placed in the ECM

Radionuclide	Total Activity (Bq)	Radionuclide	Total Activity (Bq)
Ag-108m	2.03×10^{11}	Pu-239	2.01×10^{12}
Am-241	5.19×10^{13}	Pu-240	3.13×10^{12}
Am-243	1.97×10^{10}	Pu-241	1.02×10^{11}
C-14	4.41×10^{13}	Pu-242	9.37×10^{9}
Cl-36	1.93×10^{11}	Ra-226	5.79×10^{11}
Co-60	4.38×10^{15}	Se-79	2.16×10^{9}
Cs-135	6.63×10^{9}	Sn-126	3.16×10^{9}
Cs-137	5.31×10^{17}	Sr-90 + Y-90	1.66×10^{15}
H-3	4.82×10^{15}(a)	Tc-99	6.88×10^{12}
I-129	1.48×10^{12}	U-233	1.88×10^{10}
Mo-93	3.51×10^{7}	U-234	3.86×10^{12}
Nb-94	2.97×10^{13}	U-235	2.49×10^{11}
Ni-59	6.68×10^{10}	U-238	1.24×10^{13}
Ni-63	2.53×10^{13}	Zr-93	1.18×10^{13}
Np-237	3.57×10^{9}		

Note:

The inventory is a reference inventory based on the existing characterized waste streams, which form a small portion of the inventory. This was extrapolated to 1,000,000 m^3 using expert opinion. While there is uncertainty with this data set, the waste quality and characterization program will assure the inventory envelope is not exceeded.

The waste inventory was estimated based on radionuclide quantities in 2020.

a) Maximum tritium inventory placed within the ECM is estimated at 4.8E15 Bq; however, waste streams with high tritium content will be placed in special packaging or decay-stored so that no more than 3.9E13 Bq will be available for leaching prior to the ECM closure.

Bq = Becquerels.

Radon emissions and tritium in leachate were estimated using RESidual RADioactivity (RESRAD) 3.1. The modelling scenario for the operations phase considered that there will be one active cell, partially filled with waste and the remaining cells will be either empty or filled with radioactive waste, and closed using an engineered cover.

Waterborne Effluent – Operations Phase

The total average annual volume of leachate, contact stormwater, and decontamination water under this operating scenario is 6,556 cubic metres per year (m^3/year). These maximum rates are calculated based on average annual precipitation, for a limiting condition in which one active cell is open and the remaining cells filled and closed. Treated effluent is discharged from the WWTP to an infiltration area ultimately leading to the East Swamp wetland. For the operations phase modelling, it is conservatively assumed that no dilution occurs prior to the East Swamp wetland. The annual average flow rate of the East Swamp stream, which drains the wetland, is 7.2×10^4 m^3/yr. Average annual outflow from this wetland is via East Swamp Stream to Perch Lake, which discharges to the Ottawa River via Perch Creek at 1.70×10^6 m^3/yr.

Both aquatic and terrestrial species will be exposed to contaminated surface water and sediment in the East Swamp Stream, Perch Lake, Perch Creek, and Ottawa River. As further dilution will occur in the Perch Lake, Perch Creek and Ottawa River, exposure within the aquatic environment of the East Swamp Stream is bounding. Therefore, doses to non-human biota were calculated based on water and sediment concentrations in East Swamp Stream.

Treated effluent discharged to the infiltration area will contain small quantities of residual contaminants. Treated wastewater will enter the East Swamp Stream, and proceed to Perch Lake, Perch Creek, and the Ottawa River as described above. The concentrations of radionuclides in the WWTP effluent are assumed to be equal to CNL's treatment targets, as presented in Table 5.7.6-2. Also presented in Table 5.7.6-2 are concentrations of radionuclides in the East Swamp Stream. They were derived by applying a dilution factor of 12.5, which was calculated based on the flow rate of 72,000 m^3/y in the East Swamp stream and the WWTP effluent flow rate of 6,556 m^3/y.

Table 5.7.6-2: Maximum Concentrations of Radionuclides in the Treated Effluent and East Swamp Stream

Radionuclide	Concentration in Treated Effluent (Bq/L)[b]	Concentration in East Swamp Stream (Bq/L)
Ag-108m	60	5.0
Am-241	0.7	0.1
Am-243	0.7	0.1
C-14	200	16.7
Cl-36	100	8.3
Co-60	40	3.3
Cs-135	70	5.8
Cs-137	10	0.8
H-3[(a)]	1.4×10^5	1.2×10^4
I-129	1	0.1
Mo-93	40	3.3
Nb-94	80	6.7
Ni-59	2,000	166.9
Ni-63	900	75.1
Np-237	1	0.1
Pu-239	0.6	0.1
Pu-240	0.6	0.1
Pu-241	0.6	0.1
Pu-242	0.6	0.1
Ra-226	0.5	0.0
Se-79	50	4.2
Sn-126	30	2.5

Table 5.7.6-2: Maximum Concentrations of Radionuclides in the Treated Effluent and East Swamp Stream

Radionuclide	Concentration in Treated Effluent (Bq/L)[b]	Concentration in East Swamp Stream (Bq/L)
Sr-90	5	0.4
Tc-99	200	16.7
U-233	3	0.3
U-234	3	0.3
U-235	3	0.3
U-238	3	0.3
Zr-93	5	0.4

a) To be determined. HTO concentration in leachate, as presented in Table 5.7.6-2, was estimated based on the projected inventory of tritium in bulk waste. This does not account for waste, which may be placed into specialized containers, designed to minimize potential emissions of tritium, or decay-stored prior to placement into the ECM.

b) Discharge limit concentration, as an upper bound.

Bq/L = Becquerels per litre.

Releases of tritium represent a special case as tritium in the form of HTO will not be removed from the leachate during processing at the WWTP via filtration and IX treatment. For this reason, concentration of tritium in effluent was estimated based on its inventory in bulk waste, leachate generation rate and the total quantity of waste water.

Waterborne Effluent – Post-Institutional Control Period

For the post-Institutional Control period (i.e., after year 2400), soil at the ECM may begin to erode and engineered barriers will deteriorate. Eventually, it is assumed that the waste, having dried out during the post-closure period of Institutional Control, will rehydrate and become partially saturated due to infiltration of precipitation through the deteriorated ECM cover. At this time, one of two plausible scenarios may take place:

- **Leaching through the Base Liner:** If the base liner fails at this time, then it will provide a pathway for the leachate to enter the groundwater. The rate at which contaminants move through the liner system and the groundwater flow system will in part be controlled by the solubility and sorption interactions that involve specific contaminants. If sufficiently mobile, the contaminants will eventually discharge to Perch Creek and thence to the Ottawa River.

- **Bathtub Effect Overflow Scenario:** If the base liner remains intact, then the infiltrating water will continue to be constrained by the ECM liner and berms. Water will enter the ECM at a rate determined by the degree of failure of the cover and percolate through the waste. Within confines of the berms the ECM will become fully saturated and leachate will discharge to surface at the lowest point of the berm. Depending on the rate of discharge the escaping leachate will infiltrate to the local groundwater flow system and may also flow overland to Perch Creek.

Both of these scenarios are analyzed as “normal evolution” scenarios which may occur immediately following the end of institutional control in the year 2400.

The concentrations of radionuclides in ECM waste at year 2400 were estimated using RESRAD as shown in Table 5.7.6-3, and were used as the source term for both post-Institutional Control period groundwater transport scenarios. These calculations account for radioactive decay and ingrowth.

Table 5.7.6-3: Concentrations of Radionuclides in the Engineered Containment Mound at Year 2400

Radionuclide	Radionuclide Concentration (Bq/g)	Radionuclide	Radionuclide Concentration (Bq/g)
Ac-227	6.70×10^{-4}	Pu-239	7.29×10^{-1}
Ag-108m	9.36×10^{-3}	Pu-240	1.11×10^{0}
Am-241	1.03×10^{0}	Pu-241	4.26×10^{-10}
Am-243	6.98×10^{-3}	Pu-242	3.44×10^{-3}
C-14	1.55×10^{1}	Ra-226	1.80×10^{-1}
Cl-36	7.07×10^{-2}	Ra-228	1.15×10^{-13}
Co-60	2.29×10^{-16}	Se-79	7.89×10^{-4}
Cs-135	2.43×10^{-3}	Sn-126	1.16×10^{-3}
Cs-137	3.00×10^{1}	Sr-90	7.18×10^{-2}
H-3	1.60×10^{-5}	Tc-99	2.52×10^{0}
I-129	5.43×10^{-1}	Th-228	1.13×10^{-13}
Mo-93	1.20×10^{-5}	Th-229	2.43×10^{-4}
Nb-93m	4.33×10^{0}	Th-230	4.86×10^{-3}
Nb-94	1.08×10^{1}	Th-232	1.20×10^{-13}
Ni-59	2.44×10^{-2}	U-233	6.89×10^{-3}
Ni-63	5.97×10^{-1}	U-234	1.42×10^{0}
Np-237	3.06×10^{-3}	U-235	9.12×10^{-2}
Pa-231	7.30×10^{-4}	U-236	1.27×10^{-5}
Pb-210	1.83×10^{-1}	U-238	4.55×10^{0}
Po-210	1.83×10^{-1}	Zr-93	4.33×10^{0}

Bq/g = Becquerels per gram.

The post-Institutional Control period groundwater transport scenarios utilized the following additional parameters and assumptions.

- The net infiltration rate through the ECM is 0.3 m/yr, assuming a catastrophic failure of the multi-layered engineered cover.
- Effective porosity of the saturated zone is 0.3 with a hydraulic conductivity of 1.7×10^{-4} metres per year (5,400 m/yr) and hydraulic gradient of 0.007 m. The depth of aquifer contributing to Perch Creek is 3 m. These parameters were derived based on site-specific parameters and adjusted by calibration to align with site-specific measurements and groundwater modelling results (Golder 2016b).
- The longitudinal dispersivity of the saturated zone is 0.3 m (Indelman et al. 1999). No lateral dispersion is assumed. The latter is a conservative assumption reflecting a relatively short transport route to Perch Creek.
- Site-specific distribution coefficients are used for aquifer and sediment. Standard values from CSA Standard N288.1-14 are used for representing retardation within the ECM (CNL 2017b).
- No credit is taken for the loss of the inventory due to the release occurring prior to the end of institutional control. This is a conservative approach, maximizing the inventory available for leaching.
- The flow rate in the Perch Creek is 1.77×10^{6} m^3/yr (5-year average) (CNL 2016c).
- Future climate, hydrological, hydrogeological conditions are the same as at present time.
- Additional parameters utilized to model contaminant transfer and dose to receptors are documented in the Performance Assessment (CNL 2017b).

For the “Leaching through Base Liner” scenario, the ECM cover and base liner are assumed to deteriorate, resulting in progressive infiltration of the cover resulting in water ingress in the waste. Contaminated leachate then enters the groundwater system, and contaminants are transported to Perch Creek and eventually flow to the Ottawa River. Waterborne emission rates from the ECM and contaminant transport into Perch Creek via groundwater were estimated using RESRAD OFFSITE. Biosphere modelling was conducted and doses to individual members of PCGs due to exposure to waterborne emissions from the NSDF were calculated using IMPACT 5.5.1.

For the “Bathtub Effect Overflow” scenario, the ECM cover is assumed to deteriorate while the base liner remains intact. As a result, water ingress causes the waste to become fully hydrated, with contaminated water eventually overtopping the ECM perimeter berm and leaching into the ground or surface water system. It was conservatively assumed that this contaminated water discharges directly into Perch Creek without any reduction in concentrations due to decay or dispersion. The resulting radionuclide flux in the overtopping leachate is calculated as shown in Table 5.7.6-4.

Resulting dose rates to non-human biota from each scenario are presented in Section 5.7.6.2 Application Case Results.

Table 5.7.6-4: Radionuclide Flux Flowing Out of the ECM during Bathtub Scenario

Radionuclide	Flux out of Contaminated Zone (Bq/yr)	Radionuclide	Flux out of Contaminated Zone (Bq/yr)
Ac-227	1.07×10^{6}	Pu-239	2.14×10^{7}
Ag-108m	2.52×10^{6}	Pu-240	3.25×10^{7}
Am-241	7.77×10^{7}	Pu-241	1.25×10^{-2}
Am-243	5.25×10^{4}	Pu-242	1.01×10^{5}
C-14	2.48×10^{10}	Ra-226	3.07×10^{6}
Cl-36	3.71×10^{8}	Ra-228	1.95×10^{-6}
Co-60	1.16×10^{-8}	Se-79	1.16×10^{5}
Cs-135	2.12×10^{5}	Sn-126	8.32×10^{4}
Cs-137	2.62×10^{9}	Sr-90	3.36×10^{7}
H-3	2.92×10^{6}	Tc-99	3.29×10^{11}
I-129	9.67×10^{8}	Th-228	2.03×10^{-7}
Mo-93	3.09×10^{3}	Th-229	4.37×10^{2}
Nb-93m	5.60×10^{7}	Th-230	8.73×10^{3}
Nb-94	1.39×10^{8}	Th-232	2.15×10^{-7}
Ni-59	5.63×10^{6}	U-233	7.19×10^{5}
Ni-63	1.38×10^{8}	U-234	1.48×10^{8}
Np-237	3.93×10^{6}	U-235	9.51×10^{6}
Pa-231	1.31×10^{4}	U-236	1.32×10^{3}
Pb-210	5.90×10^{7}	U-238	4.75×10^{8}
Po-210	5.81×10^{8}	Zr-93	2.80×10^{7}

Bq/yr = Becquerels per year.

Airborne Releases – Operations Phase

During operations, the ECM may lead to airborne radionuclide releases. Potential discharges include emissions of radioactive dust during handling of bulk materials and gaseous emissions during storage and disposal of radioactive materials. The expected gaseous radionuclide releases are:

- Tritium in the form of HTO.
- Gases containing C-14.
- Radon (Rn-222) will additionally be released due to the decay of Ra-226, Pu-242, U-234, and U-238.

Airborne emission rates are calculated for 2070, when there is a maximum amount of waste in the ECM (i.e., just before closure). Source term decreases from this point onwards. Emission rates of tritium and carbon-14 were estimated based on empirical ratios between radionuclide content in the waste and releases (NWMO 2011):

- HTO: 1% of the inventory per year, based on historical operational data;
- C-14: 0.07% of the inventory per year, based on historical operational data; and
- Rn-222: evaluated using RESRAD Offsite software, based on ingrowth in the disposed waste and migration through the waste material. The methodology is described in Appendix C of the user's manual for RESRAD (onsite) (Argonne National Laboratory 2001).

The contribution from fugitive emissions is considered to be negligible in comparison to ECM releases. Resulting airborne emission rates are displayed in Table 5.7.6-5.

Table 5.7.6-5: Airborne Emission Rates from the Engineered Containment Mound during Operations

Radionuclides	Airborne Emission Rate at Year 2070 (Bq/s)
H-3	1.24×10^{4}
C-14	9.79×10^{2}
Rn-222	4.17×10^{-3}

Note: Radon dose is very small given its low emission rate and therefore it is not considered further.
Bq/s = Becquerels per second

After closure of the ECM, the installation of the engineered cover and decay of radionuclides will result in lower gaseous discharges. Therefore, gaseous emissions during the post-closure phase are bounded by those during the operational phase. For this reason, only the gaseous emissions and dose resulting from the operations phase are assessed.

5.7.6.1.2 Exposure Pathways

The pathways considered for ecological receptors include exposure to air, water, soil, sediment, and dietary components. Conceptual diagrams displaying exposure pathways for aquatic and terrestrial receptors are shown in Figure 5.7.6-1 and Figure 5.7.6-2, respectively. In addition to these environmental pathways, some receptors may be exposed to direct gamma radiation from waste stored at the NSDF Project site. Interactions within receptor categories are not shown.

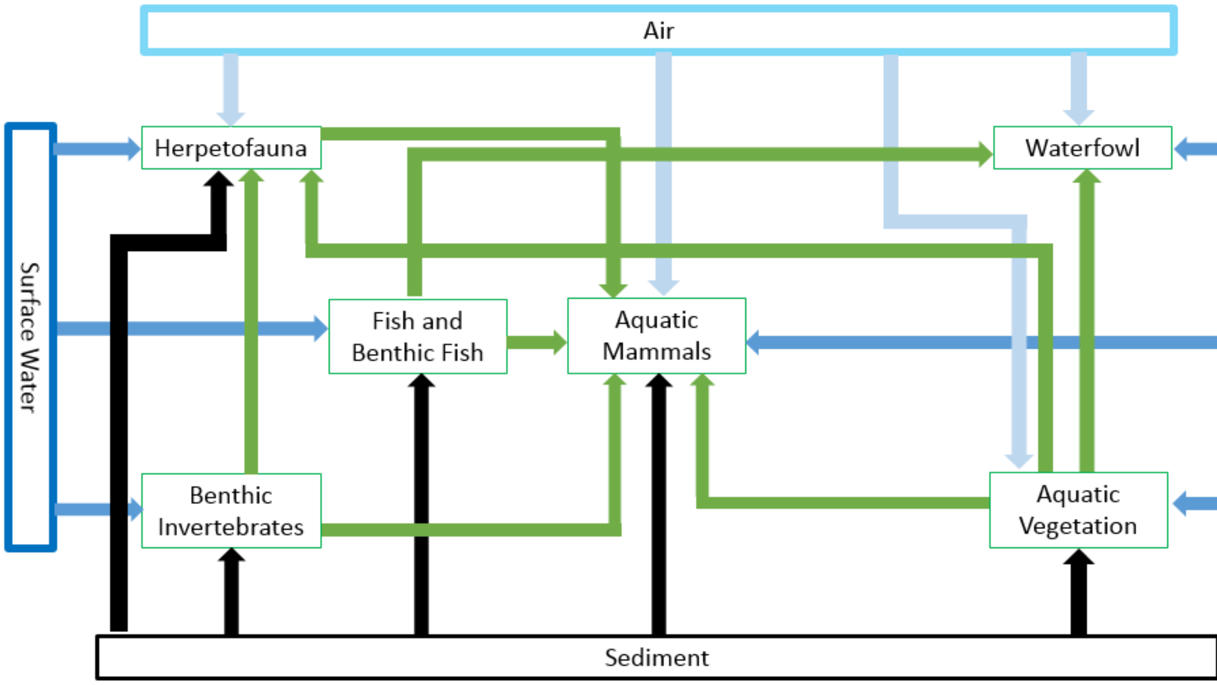


Figure 5.7.6-1: Conceptual Diagram for Aquatic Non-human Biota Exposure

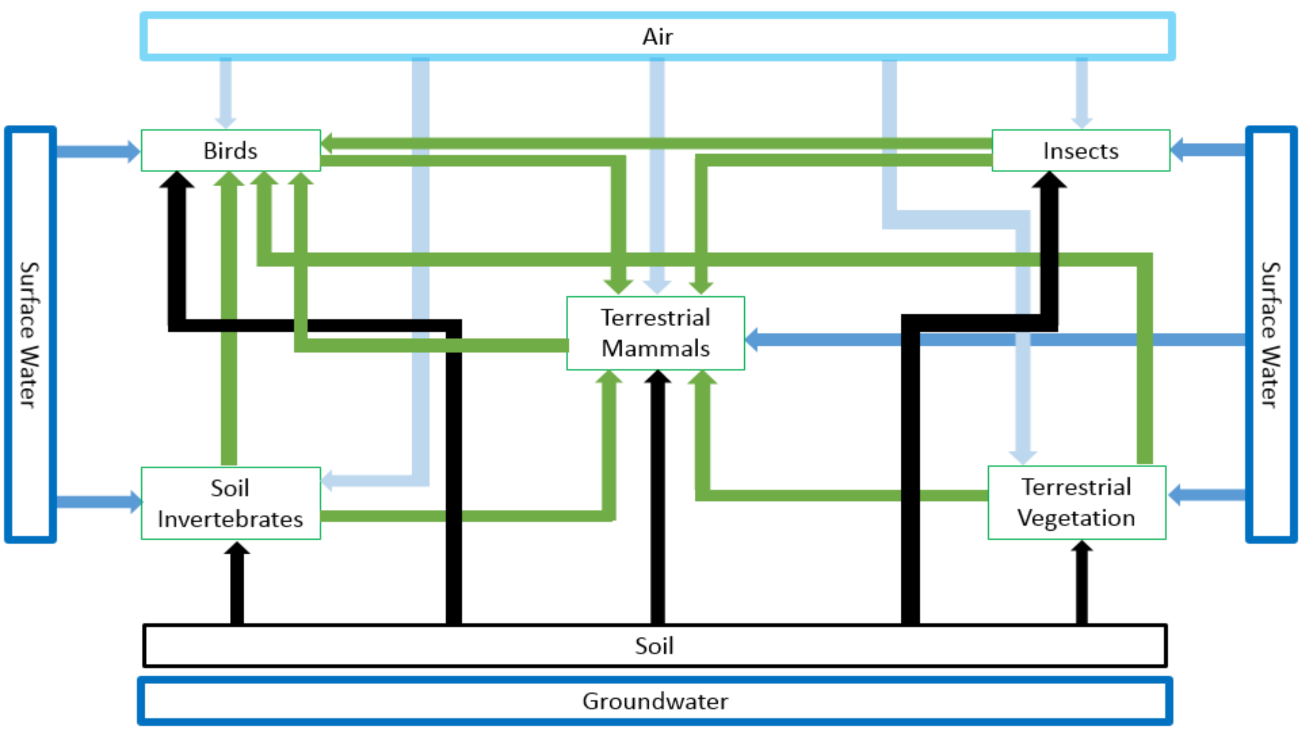


Figure 5.7.6-2: Conceptual Diagram for Terrestrial Non-human Biota Exposure

5.7.6.1.3 Exposure Assessment

Doses to non-human biota were calculated in accordance with Canadian Standards Association Standard N288.6-12 (CSA 2012). CSA N288.6-12 is the current Canadian standard which provides guidance for the assessment of dose to non-human biota resulting from the operation of nuclear facilities. Internal and external doses due to exposure from all environmental pathways are discussed below.

Internal Dose

Internal dose is calculated as follows:

$$D_{int} = DC_{int} \times C_t$$

where:

D_{int} = Internal dose rate (µGy/day)

DC_{int} = Internal dose coefficient for aquatic or terrestrial organism (µGy/day per Bq/kg)

C_t = Radionuclide concentration in tissue of the aquatic or terrestrial organism (Bq/kg)

The internal dose to any organism is calculated based on concentrations of radionuclides in the tissue of the organism (referred to as tissue concentration). The tissue concentration could be determined based on the measurement of field samples. If monitoring data is not available, the tissue concentration can be derived based on environmental media concentrations and transfer factors. Specifically, for plants, invertebrates and fish, the tissue concentration can be calculated with the following equation:

$$C_t = C_m \times BAF$$

where:

C_t = tissue concentration[3] (Bq/kg)

C_m = environmental media concentration (Bq/L or Bq/kg)

BAF = Indicator-specific, media-dependent bioaccumulation factors (L/kg or kg/kg)

For birds and mammals, the tissue concentration can be calculated with the following equation:

$$C_t = \sum (C_x \times I_x \times TF)$$

where for a given radionuclide:

C_x = concentration in the food chain item, x, of the bird or mammal (Bq/kg)

I_x = ingestion rate of the food item, x (kg/day)

TF = Indicator-specific transfer factor (day/kg)

[3] Note that the concentration data in this calculation are on a fresh weight (fw) basis.

External Dose

External dose to aquatic organisms can be calculated with the following equation:

$$D_{ext} = DC_{ext}\{[OF_w + 0.5 \times OF_{ws} + 0.5 \times OF_{seds}] \times C_w + [OF_{sed} + 0.5 \times OF_{seds}] \times C_s\}$$

where:

D_{ext} = External dose rate (μGy/day)

DC_{ext} = External dose coefficient (μGy/day per Bq/kg)

C_s = radionuclide concentration in sediment (Bq/kg)

C_w = radionuclide concentration in water (Bq/L)

OF_w = Fraction of time in water (unitless)

OF_{ws} = Fraction of time on water surface (unitless)

OF_{sed} = Fraction of time in sediment (unitless)

OF_{seds} = Fraction of time on sediment surface (unitless)

External dose to terrestrial organisms can be calculated with the following equation:

$$D_{ext} = \left(DC_{ext,s} \times OF_s \times C_s\right) + (DC_{ext,ss} \times OF_{ss} \times C_{ss})$$

where:

D_{ext} = External dose rate (μGy/day)

$DC_{ext,s}$ = External dose coefficient for exposure in soil (μGy/day per Bq/kg)

$DC_{ext,ss}$ = External dose coefficient for exposure on soil surface (μGy/day per Bq/m^2)

C_s = radionuclide concentration in soil (Bq/kg)

C_{ss} = radionuclide concentration in soil surface (Bq/m^2)

OF_s = Fraction of time in soil (unitless)

OF_{ss} = Fraction of time on soil surface (unitless)

The values of all parameters in these equations were obtained from the appropriate CSA or International Commission on Radiological Protection (ICRP) references as described in the following sections. All datasets used in the assessment are provided in the Performance Assessment (CNL 2017b).

Dose Coefficients

Dose coefficients used in this assessment are based on the International Commission on Radiological Protection (ICRP) Publication 108 (ICRP 2008).

The following weighting factors were used for calculating the internal dose coefficients for tritium and alpha emitters:

- For tritium, the weighting factor, or relative biological effectiveness, of 2 is used to calculate the weighted internal Dose Coefficient (DC).
- For other radionuclides, the weighted internal DCs are calculated as follows:

$$Weighted\ DC = (unweighted\ DC \times fraction\ of\ alpha\ component \times 10) + (unweighted\ DC \times (1 - fraction\ of\ alpha\ component)$$

The value of the fraction of alpha component for a specific radionuclide is available in ICRP 108 (ICRP 2008).

Transfer Factors

In this assessment, the Bioaccumulation Factor (BAF) and Transfer Factor (TF) are used to estimate radionuclide concentrations in indicator species. This is consistent with CSA Standard N288.6-12 (CSA 2012). These consist of the following:

- Transfer from water to fish, aquatic plant, amphibian and benthic invertebrate.
- Transfer from soil to invertebrate.
- Transfer from air and soil to plant.
- Transfer from air (inhalation), soil (intake), water (intake), and foodstuff to mammal and birds.

Transfer Factors are primarily from ICRP 114 (ICRP 2009) and CSA Standard N288.1-14 (CSA 2014).

The following process was used for calculating the dose to non-human biota:

1) Calculate waterborne and airborne emission rates.
2) Calculate concentrations in water and air based on the estimated emission rates.
3) Calculate concentration in sediment based on the estimated concentration in water.
4) Calculate doses to non-human biota based on the results of steps 3 and 4 and the equations specified above.
5) Compare the estimated doses against the assessment criteria.

Aquatic and terrestrial species are assumed to be exposed to contaminated surface water and sediment in the East Swamp Stream, Perch Lake, Perch Creek, and Ottawa River. Doses to non-human biota were calculated based on water concentrations in the East Swamp Stream; this is a bounding assumption since

significant dilution will occur at Perch Lake, Perch Creek, and the Ottawa River, which are downstream of the East Swamp Stream.

The concentrations of radionuclides in sediment in East Swamp Stream were estimated using the following equation:

$$C_s = C_w \times K_d$$

where:

C_s = concentrations of radionuclides in sediment, Bq/kg (dw)

C_w = concentrations of radionuclides in water, Bq/L

K_d = partition coefficient, taken from CSA Standard N288.1-14 (CSA 2012)

The concentrations of HTO and C-14 in air were estimated using IMPACT, based on the release rates shown in Table 5.7.6-5. Radionuclide concentrations were estimated for four locations, which are to the north, south, west and east of the NSDF site, each approximately 300 m from the source. This places assumed exposure locations within the site boundary. Although some individual species could reside closer to the emission source, the endpoint of concern is potential impact on populations of indicator species rather than individual species. Habitat ranges for all indicator species significantly exceed the 300 m radius; therefore, selected exposure locations are appropriate for the purpose of protection of species at the population level.

Calculated radionuclide concentrations in water, sediment, and air are presented in the Performance Assessment for the normal operations and post-closure scenarios described in Section 5.7.6.1.1 Contaminants. As discussed, gaseous emissions during the post-closure phase are bounded by those during the operational phase. For this reason, airborne concentrations of radionuclides during the post-closure phase are conservatively assumed to be equal to those calculated for the operations phase.

5.7.6.2 Application Case Results

5.7.6.2.1 Operations

Doses to non-human biota were calculated based on waterborne and airborne emissions, as well as external gamma radiation dose. It is assumed that all species are exposed to a dose rate of 10 micrograys per hour (µGy/h), which is based on the dose constraint of 10 µSv/h at the NSDF fence line specified for the NSDF design. Operations phase results are presented in Table 5.7.6-6. The calculated dose rates for non-human biota are compared to benchmark values suggested by CSA Standard N288.6-14 (CSA 2014), which are 100 µGy/h and 400 µGy/h for terrestrial and aquatic biota, respectively. Results indicate that the predicted doses to all indicator species are below the dose benchmark values. Doses to Bald Eagle, the most exposed species, account for 24 µGy/hr, or 24% of the benchmark value. This dose is primarily due to the waterborne emissions pathway (i.e., consumption of contaminated fish is 14 µGy/h) and direct exposure to external gamma radiation from the emplaced waste (assumed to be 10 µGy/hr). It is noted that non-human biota exposed to the aquatic habitat of East Swamp Stream are included in these dose calculations. The use of this exposure location provides a bounding assumption as it is associated with a minimum dilution, as compared to downstream waterbodies (Perch Lake, Perch Creek, Ottawa River).

Table 5.7.6-6: Doses to Non-human Biota during the Operations Phase

Taxa	Indicator	Dose due to Direct Exposure (µGy/h)	Dose due to Waterborne Emission (µGy/h)	Dose due to Airborne Emission (µGy/h)	Total Dose (µGy/h)	Benchmark (µGy/h)	% of Benchmark
Aquatic Plant	Reed	10	70	0	80	400	20%
Fish	Bluntnose minnow	10	80	0	90	400	20%
	Black Bullhead	10	70	0	80	400	20%
	Pike	10	70	0	80	400	20%
Terrestrial Plant	Red Maple	10	0	0.002	10	100	10%
Insect	Monarch Butterfly	10	0	0.002	10	100	10%
Mammal	Little brown Myotis	10	0.02	0.003	10	100	10%
	Meadow Vole	10	0.02	0.0006	10	100	10%
	White-tailed deer	10	0.2	0.003	10	100	10%
	Short-tailed Shrew	10	0.02	0.001	10	100	10%
	Eastern Wolf	10	0.4	0.005	10	100	10%
Reptile	Snapping Turtle	10	10	0	20	100	20%
	Common Watersnake	10	7	0	20	100	20%
	Eastern Milksnake	10	0	0.001	10	100	10%
Amphibian	Green Frog	10	10	0	20	100	20%
Bird	Canada Warbler	10	0.01	0.003	10	100	10%
	Eastern Whip-poor-will	10	0.01	0.003	10	100	10%
	Purple Finch	10	0.01	0.003	10	100	10%
	Ruffed Grouse	10	0.01	0.0007	10	100	10%
	Belted Kingfisher	10	7	4×10^{-6}	20	100	20%
	Bald Eagle	10	10	0.0001	20	100	20%
	Mallard	10	8	4×10^{-6}	20	100	20%
	Great Blue Heron	10	10	4×10^{-6}	20	100	20%
Invertebrate	Earthworm	10	0	0.001	10	100	10%
	Crayfish	10	30	0	40	400	9%

µGy/h = micrograys per hour.

5.7.6.2.2 Post-closure

Doses to non-human biota in the post-institutional control period of the post-closure phase are shown in Table 5.7.6-7 for the “Leaching through Base Liner” scenario, and Table 5.7.6-8 for the “Bathtub Effect Overflow” scenario. Due to the shielding provided by the cover and select material, external exposure of the public (and biota) to gamma radiation after the end of Institutional Control is not considered a plausible pathway. Doses to non-human biota arising from airborne emissions are bound by those shown in Table 5.7.6-6. Results indicate that the predicted doses to all indicator species during the post-Institutional Control period are below the dose benchmark values.

Table 5.7.6-7: Doses to Indicator Species due to Exposure to Waterborne Emissions for Post-Institutional Control “Leaching through Base Liner” Scenario

Taxa	Indicator	Dose due to Waterborne Emission (μGy/h)	Dose due to Airborne Emission (μGy/h)	Total Dose (μGy/h)	Benchmark (μGy/h)	% of Benchmark
Aquatic Plant	Reed	10	0	10	400	3%
Fish	Bluntnose minnow	7	0	7	400	2%
	Black Bullhead	7	0	7	400	2%
	Pike	7	0	7	400	2%
Terrestrial Plant	Red Maple	0	0.002	0.002	100	0.00%
Insect	Monarch Butterfly	0	0.002	0.002	100	0.00%
Mammal	Little brown Myotis	1×10^{-6}	0.003	0.003	100	0.00%
	Meadow Vole	4×10^{-6}	0.0006	0.0006	100	0.00%
	White-tailed deer	0.04	0.003	0.05	100	0.05%
	Short-tailed Shrew	3×10^{-6}	0.001	0.001	100	0.00%
	Eastern Wolf	0.1	0.005	0.1	100	0.1%
Reptile	Snapping Turtle	3	0	3	100	3%
	Common Watersnake	3	0	3	100	3%
	Eastern Milksnake	0	0.001	0.001	100	0%
Amphibian	Green Frog	3	0	3	100	3%

Table 5.7.6-7: Doses to Indicator Species due to Exposure to Waterborne Emissions for Post-Institutional Control “Leaching through Base Liner” Scenario

Taxa	Indicator	Dose due to Waterborne Emission (µGy/h)	Dose due to Airborne Emission (µGy/h)	Total Dose (µGy/h)	Benchmark (µGy/h)	% of Benchmark
Bird	Canada Warbler	$2{\times}10^{-5}$	0.003	0.003	100	0%
	Eastern Whip-poor-will	$6{\times}10^{-5}$	0.003	0.003	100	0%
	Purple Finch	$4{\times}10^{-5}$	0.003	0.003	100	0%
	Ruffed Grouse	0.0003	0.0007	0.001	100	0%
	Belted Kingfisher	4	$4{\times}10^{-6}$	4	100	4%
	Bald Eagle	4	0.0001	4	100	4%
	Mallard	4	$4{\times}10^{-6}$	4	100	4%
	Great Blue Heron	4	$4{\times}10^{-6}$	4	100	4%
Invertebrate	Earthworm	0	0.0001	0.001	100	0%
	Crayfish	8	0	8	400	2%

µGy/h = micrograys per hour.

Table 5.7.6-8: Doses to Indicator Species due to Exposure to Waterborne Emission for Post-Institutional Control “Bathtub” Scenario

Category	Indicator	Dose due to Waterborne Emission (µGy/h)	Dose due to Airborne Emission (µGy/h)	Total Dose (µGy/h)	Benchmark (µGy/h)	% of Benchmark
Aquatic Plant	Reed	30	0	30	400	7%
Fish	Bluntnose minnow	30	0	30	400	6%
	Black Bullhead	20	0	20	400	6%
	Pike	20	0	20	400	6%
Terrestrial Plant	Red Maple	0	0.002	0.002	100	0%
Insect	Monarch Butterfly	0	0.002	0.002	100	0%
Mammal	Little brown Myotis	$6{\times}10^{-5}$	0.003	0.003	100	0%
	Meadow Vole	0.0002	0.0006	0.0008	100	0%
	White-tailed deer	0.05	0.003	0.06	100	0%
	Short-tailed Shrew	0.0001	0.001	0.001	100	0%
	Eastern Wolf	0.1	0.005	0.1	100	0%

Table 5.7.6-8: Doses to Indicator Species due to Exposure to Waterborne Emission for Post-Institutional Control "Bathtub" Scenario

Category	Indicator	Dose due to Waterborne Emission (μGy/h)	Dose due to Airborne Emission (μGy/h)	Total Dose (μGy/h)	Benchmark (μGy/h)	% of Benchmark
Reptile	Snapping Turtle	10	0	10	100	10%
	Common Watersnake	10	0	10	100	10%
	Eastern Milksnake	0	0.001	0.001	100	0%
Amphibian	Green Frog	10	0	10	100	10%
Bird	Canada Warbler	5×10^{-5}	0.003	0.003	100	0%
	Eastern Whip-poor-will	0.0001	0.003	0.003	100	0%
	Purple Finch	8×10^{-5}	0.003	0.003	101	0%
	Ruffed Grouse	0.0007	0.0007	0.001	100	0%
	Belted Kingfisher	5	4×10^{-6}	5	100	5%
	Bald Eagle	9	0.0001	9	100	9%
	Mallard	7	4×10^{-6}	7	100	7%
	Great Blue Heron	6	4×10^{-6}	6	100	6%
Invertebrate	Earthworm	0	0.001	0.001	100	0%
	Crayfish	50	0	50	400	10%

μGy/h = micrograys per hour.

5.7.7 Prediction Confidence and Uncertainty

Table 5.7.7-1 describes key uncertainties in assessing residual effects from the NSDF Project on ecological health and how conservatism in the analysis and assumptions addressed these uncertainties.

Table 5.7.7-1: Uncertainties in the Ecological Health Assessment

Parameter	Uncertainty	Conservatism and Assumptions
Waste Inventory	There is uncertainty with regards to the inventory of radionuclides that have been accumulated over the decades of operation of CRL site, as well as the projected inventory of wastes that will be generated in the future.	■ Estimates of the total ECM inventory were made conservatively using available data on wastes that are currently stored at CRL site. ■ Both already accumulated wastes and those that will be generated in the future will have to meet NSDF WAC.
Source Term	There is uncertainty associated with airborne and groundwater release rates.	■ Waterborne releases from the WWTP are assumed to contain contaminants at maximum permissible concentrations. This is a bounding assumption; in most cases concentrations will be a small fraction of maximum permissible concentrations. ■ Airborne releases from the ECM are based on empirical data for C-14 and HTO and on a conservative model for Radon. The estimates neglect loss of contaminants over time, and decay as they migrate through the cover of capped cells.
ECM Performance	There is uncertainty with regards to when protective barriers may begin to fail due to erosion or other natural events.	■ ECM includes multiple protective barriers in the cover and base liner, designed to isolate the waste even in the event if one or more of the barriers were to fail. ■ ECM can be maintained and monitored during the period of institutional control. Any issues identified during this period can be mitigated. ■ Two conservative scenarios involving major failures of the cover and base liner were considered. It was assumed that the failure of the liner and cover would occur immediately following the end of institutional control.
Conceptual model	This uncertainty is associated with conceptual model for groundwater flow and potential future impacts on it resulting from the climate change	■ Current groundwater flow and contaminant transport in Perch Lake area are well understood due to decades of data available for the site. ■ Groundwater flow model was calibrated against the available datasets based on the existing plumes emanating from WMA and LDA. ■ For the post-Institutional Control period scenario it was conservatively assumed that an instantaneous discharge into Perch Creek. This provides a limiting assumption for any future changes that may occur, which may influence environmental transport parameters.
Leaching and Transport parameters	Parameter uncertainty may lead to underestimation of doses to members of the public and non-human biota	■ The site characteristics are well understood owing to many decades of monitoring. In any case, conservative and bounding assumptions were used as described above. ■ Use of conservative values for sensitive parameters. A lower K_d for leaching from the ECM was considered in one of the sensitivity scenarios in the Performance Assessment.

Table 5.7.7-1: Uncertainties in the Ecological Health Assessment

Parameter	Uncertainty	Conservatism and Assumptions
Assessment of doses to non-human biota	There is uncertainty in the modelling parameters for atmospheric and waterborne exposure pathways	Conservative exposure parameters were used, consistent with the quantitative risk assessment methodology described in CSA N288.6 (CSA 2012).
Assessment of radiological risks to populations of non-human biota	There is uncertainty in the dose criteria used for non-human biota	■ While there is a variation of dose benchmarks in various jurisdictions, care should be taken in ensuring that they are fit for use. ■ In particular a screening level of 10 µGy/h should be considered as "below concern" based on generic screening calculations. If this level is exceeded, then a more detailed evaluation is required above such levels (Anderson 2009). ■ As such, this is a minimum level, which is not meant to be a limiting criterion. ■ Benchmarks selected for this assessment are consistent with Canadian ERA (CSA 2012). They are appropriate for the site-specific quantitative ecological risk assessment conducted for the NSDF.
Modelling Tool uncertainty	Uncertainty associated with conceptual models built within RESRAD and IMPACT codes.	■ Numerical uncertainty in the selected models has been evaluated through model validation. Model validation answers the question "Does the model accurately simulate the behaviour of the system?" Both RESRAD and IMPACT codes have undergone extensive validation for the pathways and exposure scenarios considered in the analysis (CNL 2017b). ■ CNSC G-320 (CNSC 2006) acknowledges that uncertainty exists in modelling, and states that the reliability of long-term quantitative predictions diminishes with increasing timescale. Long term quantitative predictions should therefore not be considered as guaranteed impacts, but rather as safety indicators. It is also stated that uncertainties in modelling should be addressed by conservatism built into the assessment model, scenario design, and parameter choice. This is consistent with the manner in which this analysis has used long-term quantitative predictions of peak dose to PCGs in the post-institutional control period. As documented within this table, modelling uncertainty is addressed with conservatism built into the model, scenario design, and parameters.
Cumulative Effect	Uncertainty associated with the cumulative effect during post-closure, taking into account releases from WMAs and LDAs in the Perch Creek Basin.	■ Canadian Nuclear Laboratories is developing an appropriate environmental remediation concept for contaminated areas. The decision-making process is based on radiological impacts. ■ It is expected that, if there is any potential to have cumulative effects exceeding safety objectives, then contaminated land from WMAs and LDAs will be removed prior to the NSDF closure.

5.7.8 Residual Effects Classification and Determination of Significance

The residual effects analysis methods for the ecological health assessment are different in some notable ways from those used by other VCs. Specifically, the assessment of potential effects to ecological health VCs results in the generation of risk factors that inherently consider the geographic extent, duration, frequency and other characteristics of the predicted changes to the environment that may result from Project activities. As such, these inherent attributes cannot be used to determine environmental significance, as they can with other components. Instead, significance for ecological health is evaluated based on: (i) the potential magnitude of the response, as indicated by the comparison to benchmarks, and (ii) the degree of conservatism and uncertainty in the analysis.

Results of the radiological dose assessment for the operations phase and Institutional Control period indicates that doses to ecological health VCs are below their respective benchmark values. Although uncertainties in the assessment exist (Section 5.7.7 Prediction Confidence and Uncertainty), conservatism has been included in the modelling so that residual effects are not greater than predicted. As such, residual effects are considered to be not significant for all ecological health VCs during the operations phase and the Institutional Control period.

5.7.9 Monitoring and Follow-up

Monitoring of environmental media at the CRL site and surrounding area will proceed as described in CNL's ongoing Environmental Monitoring Program (CNL 2016c). As described in Section 5.7.4.3 Environmental Monitoring Program, this includes sampling and analysis of surface water, groundwater, sediment, soil, vegetation, ambient air, milk, garden produce, game animals, farm animals, and fish. Sections 5.7.4.4 Radioactivity in the Atmospheric Environment to 5.7.4.10 Radioactivity in Terrestrial Foodstuffs provide additional details regarding the scope of these programs for monitoring radioactivity in environmental media.

Emissions and effluents from the NSDF Project during the construction, operations, closure, and post-closure phases will be managed in accordance with CNL's procedure Management and Monitoring of Emissions. This procedure defines the key requirements, responsibilities, and processes for the management of radioactive and non-radioactive emissions at the NSDF. The Environmental Protection Plan prepared for the NSDF Project expands on the regulatory requirements of CSA Standard N288.5-11 for the management of these emissions. For example, operational control monitoring will be completed to confirm emission controls and treatment systems are functioning as intended. In addition, effluent monitoring will be completed to verify that emissions meet treatment targets.

An effluent verification monitoring program (EVMP) will be established for the monitoring of radioactive and non-radioactive emissions estimated from the NSDF Project. The EVMP at the NSDF Project is required to demonstrate compliance with the CRL NSDF site Derived Release Limits, which are used to ensure that the dose to ecological health VCs as a result of operation of the site is below their respective benchmark values.

5.7.10 Conclusions

For ecological health, representative receptor taxa were selected as Valued Components (VCs), as documented in Section 5.7.2 Valued Components. Assessment endpoints are qualitative expressions used to assess the significance of residual effects on VCs and represent the key properties of the VC that should be protected for future human generations (i.e., incorporates sustainability). The assessment endpoint is the protection of ecological health. Measurement endpoints represent properties of the environment, that when changed, could result in or contribute to an effect on an assessment endpoint. Measurement endpoints for the ecological health assessment include changes in air quality, groundwater quality, and surface water quality.

Radiological dose to non-human biota may result from waterborne or airborne emissions from the NSDF Project. Dose to non-human biota from waterborne emissions is calculated during the operations phase, as well as during the post-Institutional Control period for the NSDF Project. Dose to non-human biota from airborne emissions is calculated only for the operations phase of the NSDF. This represents the bounding case, since it is expected that doses to non-human biota during the post-closure would be less than the operations phase with the installation of the final cover. It is assumed that all species are exposed to a dose rate of 10 μGy/h prior to closure of the NSDF, which is the limiting design criterion at the NSDF Project fence line. Results indicate that the predicted doses to all indicator species are below the dose benchmark values for the operations phase and post-Institutional Control period.

Although uncertainties in the assessment exist, conservatism has been included in the modelling so that residual effects are not greater than predicted. As such, residual effects are considered to be not significant for all ecological health VCs during the operations phase and the post-Institutional Control period. Monitoring and follow-up programs are described in Section 5.7.9 Monitoring and Follow up and include implementation of CNL's existing Environmental Monitoring Program and EVMP, as well as NSDF-specific environmental monitoring activities. These programs will verify effects predictions for ecological health.

5.8 Human Health

This section of the Environmental Impact Statement (EIS) for the Canadian Nuclear Laboratories (CNL) Near Surface Disposal Facility (NSDF) Project summarizes the results of the Environmental Risk Assessment (ERA), specifically as it relates to effects to human health from changes in ambient radioactivity and non-radiological substances. Baseline information on radiological parameters in the environment that are relevant to human health are summarized in Section 5.7, and non-radiological parameters are summarized in the discipline-specific sections.

5.8.1 Scope of the Assessment

The human health assessment follows the overall environmental assessment approach and methods described in Section 5.1. The assessment is completed in the following key steps:

- **Step 1 – Identify Valued Components (VCs) and define the spatial boundaries, temporal boundaries, and assessment cases** for the ambient radioactivity assessment (refer to Sections 5.8.2 Valued Components and Section 5.8.3 Assessment Boundaries). The VCs and measurement indicators used to assess NSDF Project related effects to human health, the spatial and temporal boundaries at which the assessment occurred, and the assessment cases considered are described.
- **Step 2 – Describe the existing conditions** (refer to Section 5.8.4 Description of the Existing Environment). Baseline data collected from Chalk River Laboratories (CRL) existing operations and background levels across Canada are discussed. The existing conditions provide a reference, from which to compare the effects of the NSDF Project to.
- **Step 3 – Evaluate Project interactions and mitigation** (refer to Section 5.8.5 Project Interactions and Mitigation). Project components and/or activities with the potential to affect human health are identified and mitigation developed to limit or avoid effects are presented. A pathways analysis is then used to focus further assessment on key interactions between the NSDF Project and the environment by evaluating the different effect pathways to determine if, after incorporation of mitigation, there is still potential to cause residual effects. Where effects are adequately mitigated and are not forwarded for further analysis (i.e., secondary pathways, or where mitigation will remove the pathway altogether), the reasons for concluding the assessment at this stage are articulated. Primary pathways that may lead to residual effects to human health after incorporating mitigation are carried forward to Step 3 for further analysis and residual effects characterization.
- **Step 4 – Present the methods and results of the residual effects analysis** (refer to Section 5.8.6 Residual Effects Analysis). This Section summarizes the methods used to predict and characterize residual effects to human health from primary effect pathways. The results of the human health assessment are presented including the characterization of residual incremental effects of the NSDF Project and the cumulative effects of the NSDF Project in combination in combination with other reasonably foreseeable developments (if applicable).

- **Step 5 – Describe the level of certainty and management of uncertainty** (refer to Section 5.8.7 Prediction Confidence and Uncertainty). Evaluate the available literature, data, and models used for the assessment, and describe the level of certainty that can be placed on predicted residual effects. This section will also identify how the uncertainty has been managed so that the effects are not underestimated.
- **Step 6 – Classify and determine the significance of the predicted residual effects** (refer to Section 5.8.8 Residual Effects Classification and Determination of Significance). Residual effects predicted from primary pathways are classified using a common set of criteria: direction, magnitude, geographic extent, duration, reversibility, frequency, and likelihood. A determination of the significance of the predicted residual effects of the NSDF Project on human health is made. Relative to other sections, the human health assessment uses a slightly different approach to the classification of residual effects and evaluation of significance, because several of the criteria (e.g., geographical extent, duration, frequency and reversibility) are already incorporated into the risk estimates and, therefore, are not independent variables.
- **Step 7 – Identify monitoring and follow-up** required to confirm effects predictions and address uncertainty (refer to Section 5.8.9 Monitoring and Follow-up).
- **Step 8 – Present a consolidated summary of conclusions** and outcomes of the assessment of residual effects on human and non-human biota (refer to Section 5.8.10 Conclusions).

Information and areas of interest raised by the public, communities of interest, regulators, and First Nations and Métis communities during engagement that influenced the scope of the human health assessment are summarized in Table 5.8.1-1. Other general concerns and questions raised during the engagement that pertain to the human health assessment (if any) are documented in Appendix 4.0-18 Public Feedback Received.

Table 5.8.1-1: Summary of Areas of Interest Raised during Engagement Activities that Influenced the Scope of the Human Health Assessment

Area of Interest	How the Area of Interest Was Included in the Assessment
Effects to fish from potential for contamination in the Ottawa River from the NSDF Project.	The spatial boundaries of the assessment were selected to include consideration of potential effects to the Ottawa River. The human health assessment considered potential changes in surface water in Perch Creek and meeting guidelines within the Perch Creek basin is considered to be protective of fish in the Ottawa River.
Potential for radioactivity from gases from the capped facility	Potential changes in air quality from the NSDF Project were evaluated in the human health assessment during the operations phase.
Potential for changes in groundwater quality to affect uses downstream of the ECM	Potential changes in groundwater quality from the NSDF Project were evaluated in the human health assessment and included potential changes from treated effluent discharge from the wastewater treatment plant (WWTP), and seepage from the engineered containment mound (ECM) during the operations phase and Institutional Control period.
Treatment of leachate	Leachate from the ECM will be collected and pumped to the WWTP for treatment prior to discharging to the infiltration area.
Potential leakage of leachate from the ECM	Potential leakage of leachate from the ECM during operations will be mitigated through the design and implementation of a composite base liner system, a leachate detection system and a leak collection system. Potential leakage from the ECM during the operations phase and Institutional Control period is considered in the human health assessment.

5.8.2 Valued Components

Valued components refer to environmental features that may be affected by a project and that have been identified to be of concern by the proponent, scientists, government agencies, First Nations and Métis peoples, or the public (Canadian Environmental Assessment Agency [the Agency] 2014). The human health risk assessment focused on worker and public health. The assessment for public health considered locations where people are known to be present (e.g., local communities, farmers, and recreational areas). Valued components and rationale for their selection for the human health assessment are provided in Table 5.8.2-1.

Table 5.8.2-1: Valued Components for the Human Health Assessment

Valued Component	Rationale for Selection
■ Worker ■ Public ▪ Residential ▪ Seasonal	■ Workers: potential external and internal radionuclide exposure ■ Public: potential exposure to airborne and waterborne radiological emissions

Assessment endpoints are qualitative expressions used to assess the significance of residual effects on VCs and represent the key properties of the VC that should be protected for future human generations (i.e., incorporates sustainability). The assessment endpoint is the protection of human health. Measurement endpoints represent properties of the environment, that when changed, could result in or contribute to an effect on an assessment endpoint. The measurement endpoints for the human health assessment are outlined in Table 5.8.2-2.

Table 5.8.2-2: Assessment Endpoints and Measurement Indicators for the Human Health Assessment

Valued Component	Assessment Endpoint	Measurement Indicators
■ Worker ■ Public ▪ Residential ▪ Seasonal	Protection of human health	■ Changes to air quality ■ Changes to groundwater quality ■ Changes to surface water quality ■ Changes to soil quality ■ Changes to vegetation quality

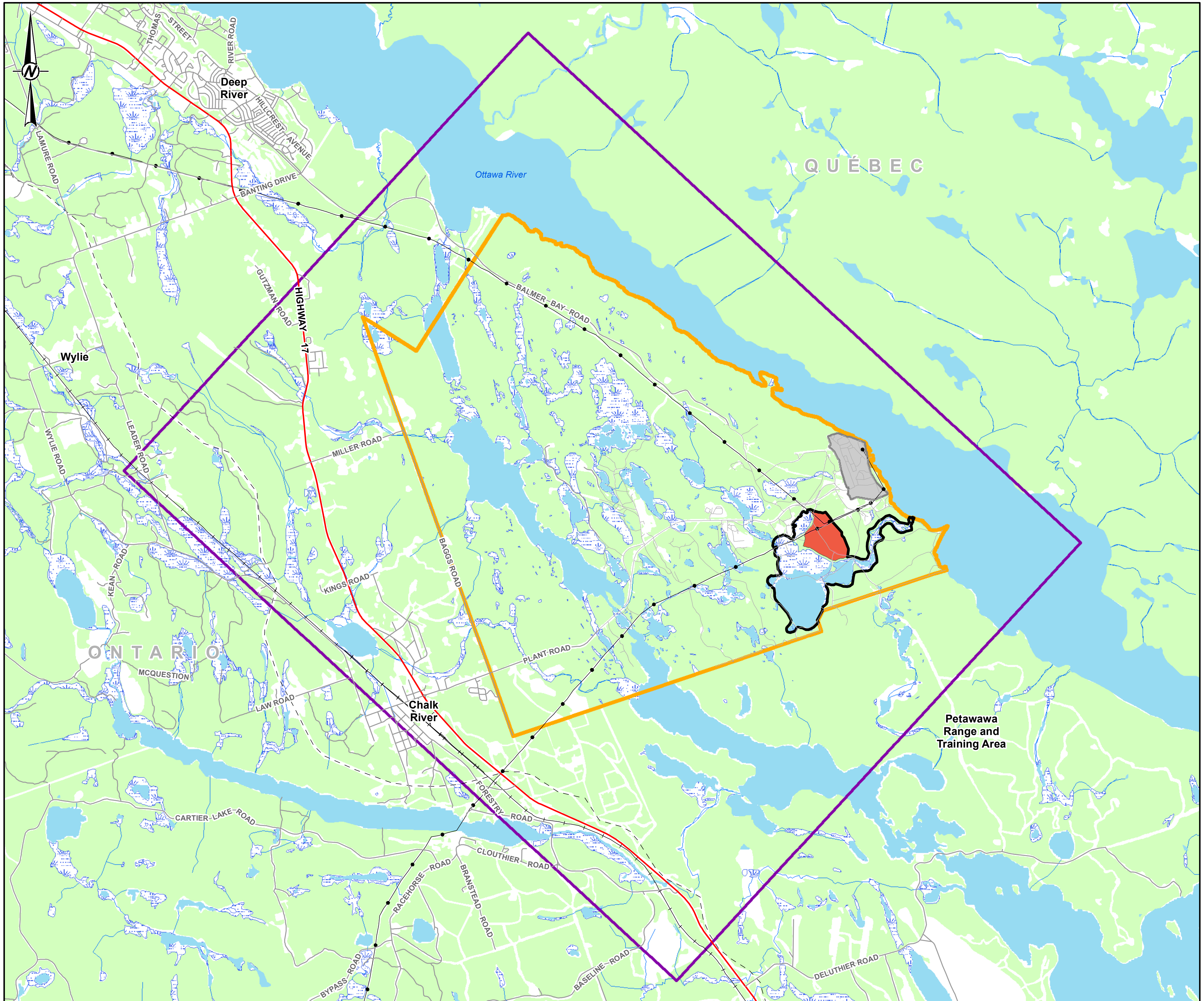
5.8.3 Assessment Boundaries

5.8.3.1 Spatial Boundaries

The spatial boundaries for the human health assessment are defined by the boundary of the Regional Study Area (RSA). The Local Study Area (LSA) is an area of greater focus within the RSA (Figure 5.8.3-1). To define the spatial boundaries for human health, the primary pathways that could contribute to residual effects on human health were determined (see Section 5.8.5). Primary pathways were identified from air quality, groundwater water quality and surface water quality. The spatial boundaries for human health were thus selected to incorporate relevant portions of the study areas for air quality, groundwater quality and surface water quality to evaluate the environmental changes that could contribute to effects on human health. The spatial boundaries for the effects assessment are as follows:

- **Site Study Area (SSA):** The SSA is the NSDF Project footprint (i.e., where Project activities would be undertaken including the NSDF Project's proposed facilities, buildings and infrastructure).
- **Local Study Area (LSA):** The LSA is defined as the area within which there is potential for measurable changes to measurement indicators resulting from the proposed NSDF Project activities. The LSA adapted from the groundwater and surface water RSA and is designated as the spatial extent of the Perch Creek watershed, and includes Perch Lake and its tributaries, and Perch Creek. The Ottawa River in the vicinity of the mouth of Perch Creek is also included in the LSA.
- **Regional Study Area (RSA):** The RSA is defined as the area within which the potential effects of the NSDF Project may interact with the effects of other existing or reasonably foreseeable projects. Humans in the vicinity of the engineered containment mound (ECM) could be exposed to airborne and waterborne emissions as well as direct gamma radiation from the waste. Therefore, the RSA was adapted from the air quality study area as this is the largest extent of potential cumulative effects on ecological health; the air quality RSA is defined as an approximate 10 kilometre (km) by 10 km rectangle surrounding the LSA, and oriented parallel to the Ottawa River.

232 509220 REPT 004
UNRESTRICTED



LEGEND

- HIGHWAY
- ROAD
- RAILWAY
- TRANSMISSION LINE
- NATURAL GAS PIPELINE
- RIVER/STREAM
- WATERBODY
- WETLAND
- WOODED AREA
- SITE STUDY AREA (NSDF PROJECT SITE)
- CRL MAIN CAMPUS
- CRL PROPERTY
- LOCAL STUDY AREA
- REGIONAL STUDY AREA

2.5 0 2.5

1:60,000 KILOMETRES

NOTE(S)

1. LIQUID DISPOSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.

REFERENCE(S)

1. BASEMAP:SOURCES: ESRI, HERE, DELORME, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), SWISSTOPO, MAPMYINDIA, © OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
2. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
3. HIGHWAYS AND FIRST NATION RESERVES MNRF 2016
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
HUMAN HEALTH STUDY AREAS

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	EM
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0001	0.0	5.8.3 1

This page left intentionally blank

5.8.3.2 Temporal Boundaries

Temporal boundaries (i.e., project phases) establish the timeframe during which NSDF Project effects are assessed. The temporal boundary represents the timeframe during which project activities are actively occurring, and does include the duration of predicted residual effects. The duration of an effect is defined as the amount of time between the start and end of a Project activity or stressor (which is related to the project phases) plus the time required for the residual effect to be reversed. In some cases, a residual effect may be irreversible within the temporal boundaries of the Project (e.g., residual effect lasts for thousands of years). The following phases were identified for the NSDF Project and considered in the assessment:

- **Construction Phase**: includes site preparation and all activities associated with the construction of the NSDF. This phase includes activities such as installing the necessary supporting and/or ancillary facilities and NSDF infrastructure to facilitate NSDF operations, inactive commissioning and systems testing, and transportation of construction materials. Construction activities are expected take place from 2018 to 2020.
- **Operations Phase**: includes all activities associated with the landfilling of waste receipt, waste placement, water management, wastewater treatment plant operations, vehicle movements into and from the NSDF Project site, and maintenance activities. Operations activities are expected to last approximately 50 years (i.e., 2020 to 2070).
- **Closure Phase:** includes activities necessary to complete the installation of the final cover and implementation of long-term monitoring. Closure activities are expected to start in 2070 and continue through to 2100, after which the NSDF Project will transfer into the post-closure phase.
- **Post-closure Phase:** has two discrete periods: Institutional Control and post-Institutional Control. The Institutional Control period includes implementation of both active and passive control throughout 2100 to 2400 (i.e., 300 years). During Institutional Control, groundwater monitoring and groundwater quality management will continue to demonstrate compliance with the safety case assumptions. Post-institutional Control occurs after year 2400 and continues indefinitely.

The temporal boundaries for the human health assessment include consideration of effects of the NSDF Project during the operations phase and the post-Institutional Control period of the post-closure phase.

5.8.3.3 Assessment Cases

The assessment cases considered in the human health assessment include the Base Case and Application Case:

- **Base Case –** This scenario represents existing conditions and characterizes combined effects from previous and existing developments and activities. The Base Case reflects the effects of existing disturbances, such as forestry, transportation, agricultural, mining, and residential and recreational development. Current effects from the existing CRL facilities and operations, for example, are considered part of the Base Case.
- **Application Case –** This scenario represents predictions of the effects of the Base Case combined with the effects that may result from the NSDF Project. The Application Case considers potential effects from the NSDF Project during the operations phase and the Institutional Control period.

- **Reasonably Foreseeable Developments (RFD) Case** – This scenario represents predictions of the cumulative effects of the Application Case, which includes the Base Case, plus projects that are currently under application review or that have officially entered a regulatory application process, and are therefore, considered reasonably foreseeable. There are no RFDs expected in the CRL property (i.e., the RSA) with the exception of new/upgrades to research and development facilities, new support infrastructure, and ongoing decommissioning and environmental restoration activities. Potential effects from these activities are not expected to spatially overlap with potential effects to human health from the NSDF Project. The NSDF Project will enable the remediation of contaminated lands and legacy waste management areas, and decommissioning of outdated infrastructure at the CRL property and CNL's other business locations to support future CNL missions. The end-state plan for the CRL site will be to return lands disturbed by site activities to a condition that is physically stable, and safe in keeping with the land use and landscape of the day. Therefore, decommissioning and environmental restoration activities are anticipated to positively affect human health. Because RFDs will either have no spatial overlap or are likely to positively affect human health, an RFD Case is not presented as part of this assessment.

5.8.4 Description of the Existing Environment

Background radiation dose from natural and anthropogenic sources and historical radiation dose from CRL operations is used to establish a baseline characterization of radiation dose for human health assessment prior to the NSDF Project.

5.8.4.1 Background Sources of Radiation and Radioactivity

This section describes the background radiation and radioactivity that is present in the environment due to natural and anthropogenic sources independent of CRL operations. The magnitude of radiation dose from natural sources varies greatly, both spatially and temporally. The main natural sources of radiation are cosmic rays; naturally occurring radionuclides in air, water, and food; and naturally occurring radionuclides in the soil, rocks and building materials used in homes (CNSC 2013).

Cosmic radiation originates from celestial events and the sun. This cosmic radiation and the secondary particles produced penetrate the Earth's atmosphere and give an external radiation dose at the Earth's surface. Naturally-occurring radionuclides such as uranium, potassium, and thorium are present in soils, rocks and building materials. These naturally occurring radionuclides also contribute to the external gamma radiation dose.

Naturally-occurring radionuclides also incorporate into plants, animals, and water from surrounding soils and rocks. Humans ingest these foodstuffs and receive an internal radiation dose. Radon gas, a product of the decay of uranium in soil, is inhaled and also contributes to the internal radiation dose. The average annual doses in Canada are shown on Figure 5.8.4-1; the total annual dose is about 1.8 millisieverts (mSv) (CNSC 2017).

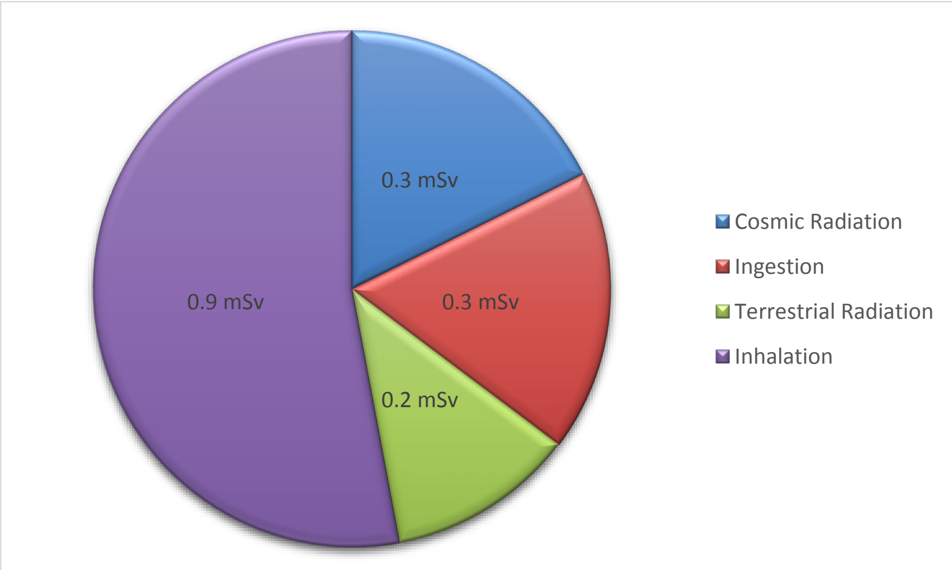


Figure 5.8.4-1: Average Background Radiation Doses in Canada (mSv/y) (CNSC 2017)

5.8.4.2 Radiation Dose from CRL Operations

Canadian Nuclear Laboratories reports the results of the Environmental Monitoring Program (EMP) for the CRL site each year to the Canadian Nuclear Safety Commission (CNSC). The EMP data is collected to verify that radiation doses to members of the public as a result of the operations of the CRL site remain as low as reasonably achievable. The calculated radiation dose to members of the public from CRL operations is shown in Table 5.8.4-1, and represents the baseline radiation dose from CRL prior to the NSDF Project. The 2015 dose assessment showed that highest radiation dose to the public from CRL operations was 0.082 millisieverts per year (mSv/yr), representing 8.2 percent (%) of the effective dose limit of 1 mSv/yr for members of the public. The 5-year average adult dose from 2011 to 2015 is 0.065 mSv/yr (CNL 2016a). The dose to members of the public is predominantly from airborne emissions.

Table 5.8.4-1: Total Dose to Critical Groups Outside the Chalk River Laboratories Boundary Based on Environmental Monitoring Results – 2011-2015

Year	Airborne Effluent Pathway – Adult Dose (mSv/yr)	Waterborne Effluent Pathway – Adult Dose (mSv/yr)
2015	0.08	0.001
2014	0.06	0.0003
2013	0.06	0.0001
2012	0.06	0.0007
2011	0.06	0.0003
5 Year Average (2011-2015)	**0.065**	**0.0005**

Source: CNL 2016a
mSv/yr = millisieverts per year.

5.8.5 Project Interactions and Mitigation

5.8.5.1 Methods

This section describes the process by which interactions between NSDF Project components and activities and human health were identified and evaluated. Potential effect pathways are identified and mitigation developed to eliminate and/or reduce effects is presented. A pathways analysis is then used to focus the assessment on key interactions between the NSDF Project and the environment by evaluating the different effect pathways to determine if, after incorporation of mitigation, there is still potential to cause residual effects. Where effects will be adequately mitigated and are not forwarded for further analysis (i.e., secondary pathways, or where mitigation will remove the pathway altogether), the reasons for concluding the assessment at this stage are articulated. Primary pathways that may lead to residual effects after incorporation of mitigation are further characterized in subsequent subsections of the assessment. As such this section helps to focus the remainder of the assessment on those interactions (effects pathways) with the potential to result in residual adverse effects.

The first part of the analysis was to identify the potential effects pathways for all stages of the NSDF Project. The next step in the analysis was the development of environmental design features and mitigation that could be incorporated into the NSDF Project to eliminate and/or reduce adverse effects to human health. Environmental design features included project design elements, environmental best practices, and management policies and procedures. Environmental design features and mitigation were developed through an iterative process between the NSDF Project's engineering and environmental teams, combined with input from project-specific or regional engagement with other interested parties. The design features and/or mitigation were selected considering their effectiveness for implementation and maintenance, and their appropriateness within the context of the identified effect pathways.

After incorporation of mitigation, potential pathways were evaluated into the following categories using scientific knowledge, logic, experience with similar developments, and the effectiveness of environmental design features and mitigation:

- **No pathway –** pathway is removed by environmental design features or mitigation such that the NSDF Project would not be expected to result in a measurable environmental change relative to Base Case values and therefore would have no residual effects to human health.
- **Secondary pathway –** the pathway could result in a measurable minor environmental change, but would have a negligible residual effect to human health relative to guideline values and is not expected to contribute cumulatively to other NSDF Project effects or to the effects of other past, present or reasonably foreseeable developments to cause a significant effect.
- **Primary pathway –** the pathway is likely to result in an environmental change relative to the guideline values that could contribute to residual effects to human health.

Environmental design features and mitigation that have been or could be incorporated into the NSDF Project to eliminate and/or reduce adverse effects were considered. Potential pathways that were completely removed due to implementation of environmental design or mitigation were not assessed further. Pathways that were assessed to be secondary and demonstrated to have a negligible residual effect to human health through simple qualitative or semi-quantitative evaluation of the pathway were also not advanced for further assessment.

Primary pathways were carried forward for more detailed quantitative and qualitative effects analysis to characterize the residual effects of the NSDF Project and the NSDF Project in combination with other past, present and reasonably foreseeable developments.

5.8.5.2 Results

Pathways through which all stages of the NSDF Project may interact with and result in changes to measurement indicators for human health is provided in Table 5.8.5-1.

Table 5.8.5-1: Pathways Analysis for Human Health Valued Components

Project Activity	Effects Pathways	Management Practices and Mitigation Actions	Pathway Assessment
■ Project activities during the operations and closure phase: ▪ Surface water management ▪ Operation of the WWTP ▪ Discharge of treated effluent from the WWTP	■ Release of emissions from the ECM from radioactive dust created during handling of bulk materials and emissions of gases during storage and disposal of radioactive materials. ■ Release of emissions from the WWTP to air during operations and closure.	■ Implementation of CNL's Procedure for Management and Monitoring of Emissions, which includes operational control monitoring and verification monitoring. ■ The Dust Management Plan for the NSDF Project will be developed and will include: ▪ restricting or suspending activities if unacceptable amounts of dust are generated due to winds or other site conditions; ▪ use of water spraying or misting techniques (e.g., water trucks) as the primary dust control method; ▪ use of fixatives (e.g., chemical suppressant) for dust control during winter season or shutdown periods, and for use as daily/interim cover; ▪ suspension of excavating, loading, hauling, and dumping operations when wind speeds exceed the specified criterion; and ▪ vehicles that have come into contact with contamination will be required to pass through the vehicle decontamination facility ■ Processed leachate will not be heated within the WWTP ■ There is active ventilation within the WWTP building and all emissions to air will be filtered prior to release.	Primary
	Discharge of treated effluent from the WWTP to the East Swamp Wetland can cause changes to surface water quality, which can affect human health.	■ The strategy for wastewater treatment is based on optimizing public and environmental protection by defining an approach to wastewater treatment that uses best demonstrated available technology that is economically achievable (BDATEA), and capable of meeting regulatory requirements. ■ The treatment target for effluent is the CRL Acceptability Criteria for Routine and Non Routine Discharge of Liquids to Stormwaters. ■ Treated effluent will be sampled and confirmed that it meets treatment targets before release to East Swamp Wetland ■ Discharge of treated effluent to the exfiltration gallery area will help to reduce water loss from the hydrogeological system.	Primary

Table 5.8.5-1: Pathways Analysis for Human Health Valued Components

Project Activity	Effects Pathways	Management Practices and Mitigation Actions	Pathway Assessment
■ Project activities during the operations and closure phase: ▪ Surface water management ▪ Operation of the WWTP ▪ Discharge of treated effluent from the WWTP	Leakage of leachate from the ECM during operations and closure may cause changes to surface water quality, which can affect human health.	■ Design of the ECM includes base contours that have been developed using a herringbone pattern with ridges and valleys to promote leachate transport to the leachate collection system for removal. ■ The base liner design includes both primary and secondary liner systems that are designed to have redundancy in case of premature failure and are a combination of natural and synthetic barrier systems. ■ The high-density polyethylene (HDPE) geomembrane for the liner was selected as it is compatible with the leachate generated by the waste and will achieve a long service life. ■ The base liner system includes an underlying compacted clay liner to supplement the primary and secondary liner system. ■ The leachate collection system design provides access points for inspections, maintenance, repairs and replacements.	No Linkage

Table 5.8.5-1: Pathways Analysis for Human Health Valued Components

Project Activity	Effects Pathways	Management Practices and Mitigation Actions	Pathway Assessment
■ Project activities during the post-closure phase: ▪ On-going long-term performance monitoring, transfer of NSDF Project into the Post-Institutional Control Period	Release of emissions of gases from the radioactive materials in the post-closure phase.	■ A passive landfill gas monitoring venting system will be constructed contemporaneously with installation of the ECM final cover system. ■ The landfill gas monitoring probes will also be installed around the perimeter of the ECM to detect evidence of potential landfill gas migration away from the ECM.	Primary
	Leakage of leachate from the ECM during the post-closure phase (i.e., after Year 2400) from liner and cover failure as a result of normal evolution can cause changes to surface water quality, which can affect human health.	■ The final cover system will be constructed to promote the shedding of surface water to mitigate infiltration into the mound, and minimize leachate generation. ■ The cover system design incorporates a series of shallow, trapezoidal, riprap-lined drainage channels that are designed to convey water at low velocity. ■ The perimeter road ditch will route the runoff around the ECM perimeter to minimize ponding of water into the closed ECM, erosion of the cover and underlying waste materials, destabilization of the ECM structure, and damage to access roads. ■ The ECM final grading and drainage plan includes collection ditches along the top of the ECM berm road to collect side slope drainage. ■ Environmental monitoring will be completed throughout the post-closure phase for the NSDF Project to confirm that the cover is functioning as intended.	Primary

5.8.5.3 No Linkage Pathways

The following pathway was assessed as having no measurable environmental change and hence, no linkage to residual effects on human health VCs.

- **Leakage of leachate from the ECM during operations and closure may cause changes to surface water quality, which can affect human health.**

Design of the ECM includes base contours that have been developed using a herringbone pattern with ridges and valleys to promote leachate transport to the leachate collection system for removal. The base liner design include both primary and secondary liner systems that are designed to have redundancy in case of premature failure and are a combination of natural and synthetic barrier systems. The primary liner will include a leachate collection system with the secondary liner housing a leak detection system. The composite base liner will contain perforated high-density polyethylene (HDPE) collection and pipes. The HDPE geomembrane was selected as it is compatible with the leachate generated by the waste and is expected to perform as an effective hydraulic and diffusion barrier over the 500-year design life (see Section 3.5.2.4). The base liner system will include an underlying compacted clay liner to supplement the primary and secondary liner system. The leachate collection system design will provide accessible access points for inspections, maintenance, repairs and replacements.

The primary liner system will contain the leachate collection system, and will convey leachate to a single collection point for removal from the mound, for transfer to the Waste Water Treatment Plant (WWTP) for treatment. The primary liner system serves as the primary source of protection for the natural environment below the mound from leachate migration. The secondary liner system will contain the leak detection system, which will be used to detect leaks in the unlikely event that the primary liner system fails. Leachate collected by the leachate collection system will be pumped to the onsite WWTP for treatment.

Designed berms consist of three main geotechnical elements, or layers, each contributing to the soundness and integrity of the berm itself and the whole ECM. A Slope Stability Analysis was completed to provide the information needed to support the design of the base slopes, sidewalls, and side slopes of the ECM. The Slope Stability Analysis addresses the range of anticipated loading conditions, under both short-term and long-term scenarios, to confirm that the slope designs will satisfy minimum factor-of-safety requirements for stability. Size and shape of the berms and each of the elements and layers were determined using a seismic design basis, including the National Building Code of Canada (NBCCC).

The implementation of these mitigation measures will reduce the potential for changes to groundwater and surface water quality from the NSDF site. As such, this pathway was determined to have no linkage to effects on human health.

5.8.5.4 Secondary Pathways

No secondary pathways were identified as having residual effect on human health.

5.8.5.5 Primary Pathways

Primary pathways identified for human health and that are evaluted in the residual effects analysis (Section 5.8.5) include:

- Release of emissions from the ECM from radioactive dust created during handling of bulk materials and emissions of gases during disposal of radioactive waste.
- Discharge of treated effluent from the WWTP to the East Swamp Wetland can cause changes to surface water quality, which can affect human health.
- Release of gases during storage and disposal of radioactive waste in the post-closure phase.
- Leakage of leachate from the ECM during the post-closure phase (i.e., after Year 2400) from liner and cover failure as a result of normal evolution can cause changes to surface water quality, which can affect human health.

5.8.6 Residual Effects Analysis

5.8.6.1 Radiological Dose Assessment

5.8.6.1.1 Application Case Methods

This section describes the specific methods used to assess the residual effects on human health for the NSDF Project activities and pathways identified as primary in Table 5.8.6-1. Policies, guidelines and standards considered in the analysis, as well as the model used to predict residual effects are described.

Radiological dose to workers on the NSDF site may result from external exposure to radiation emitted from radioactive waste or wastewater, and inhalation of radioactive contaminants in the ECM, WWTP or support buildings (e.g., Vehicle Decontamination Facility). Doses to workers will be monitored and managed as part of the NSDF Radiation Protection Plan, which is in accordance with CNL's site-wide Radiation Protection Program. As a result of the implementation of the Radiation Protection Plan, doses to workers will be kept As Low As Reasonable Achievable (ALARA) and below the effective dose limit of 100 mSv over 5 years, and below 50 mSv in any single year. Worker dose is being assessed as part of the Safety Analysis Report. Therefore, radiological dose to workers is not quantitatively assessed in the EIS.

Radiological dose to members of the public may result from waterborne or airborne emissions from the NSDF Project. Dose to members of the public from waterborne emissions is calculated during the operations phase, as well as during the post-Institutional Control period (i.e., after year 2400) of the post-closure phase for the NSDF Project. It is assumed that during the Institutional Control period (year 2100 to year 2400), the ECM liner and cover will be functional and no leachate will seep through the ECM liner.

Dose to members of the public from airborne emissions is calculated only for the operations phase of the NSDF. This represents the bounding case, since it is expected that doses to members of the public during the post-closure would be less than the operations phase with the installation of the final cover. Releases to air from the WWTP are considered to be negligible compared to estimated releases from ECM and therefore, have not been included in the assessment.

5.8.6.1.1.1 Receptor Selection

Human receptors are represented by Potential Critical Groups (PCGs). Potential Critical Groups are an identifiable, relatively homogeneous group of members of the public who, as a result of their location, age, diet, and habits, are representative of those people expected to receive the highest radiation doses as a result of radionuclide emissions from a given source. The Potential Critical Groups which have been identified for the CRL site survey are shown in Table 5.8.6-1, along with their distance to the NSDF. Potential Critical Groups were selected based on CNL's Derived Release Limits (DRL) report (AECL 2011). The critical groups listed in Table 5.8.6-1 are those that are likely to receive the highest radiation doses as a result of CRL operations. The groups identified for the air effluent pathway are located upstream of the Ottawa River and will not be exposed to waterborne releases, however, they are more likely to be exposed to higher levels of releases to air due to proximity to the source of releases to atmosphere. Liquid Effluent PCG may be exposed to both liquid and atmospheric releases. It is noted that some of these PCG locations (e.g., Petawawa, Pembroke) are outside of the RSA, as defined in Section 5.8.3.1.

Table 5.8.6-1: Potential Critical Groups for Chalk River Laboratories

Air Effluent PCGs		Liquid Effluent PCGs	
Location	**Distance to NSDF (km)**	**Location**	**Distance to NSDF (km)**
Cottager	3	Cottager	3
Mountain View	8	Laurentian Valley	36
Balmer Bay	7	Pembroke	30
Chalk River	5	Petawawa	25
Deep River	12		

km = kilometres.

Based on the PCGs identified above, the following two types of PCGs were considered in the analysis of dose to human receptors:

- residential (homes established on the shore of the Ottawa River and communities that are serviced with water drawn from the Ottawa River); and,
- seasonal (cottages on the shore of the Ottawa River).

In addition, a hypothetical PCG was added to the assessment. This group was assumed to live on the shores of the Ottawa River, adjacent to the Perch Creek outfall. In this scenario, the dilution is minimized as the additional dilution within the Ottawa River is not credited, which results in a bounding estimate of future doses (CNL 2017). The hypothetical groups will consume locally produced food at twice the rates of the lifestyle survey.

5.8.6.1.1.2 Receptor Characterization

Potential critical groups are categorized into three age classes as defined in CSA N288.1-14 (CSA 2014). These are Adult, Child and Infant. Age classes are differentiated based on PCG habits such as intake rates and dose coefficients, which are used for calculating dose. The pathway analysis model and population habits used in the existing Chalk River DRL document (AECL 2011) were used as the basis for the assessment of dose to PCGs as a result of the NSDF project. Some modifications were made account for future conditions corresponding to various evolution scenarios. The modifications also addressed biosphere transfers of additional radionuclides, which needed to be considered in the context of disposal (CNL 2017).

Cottagers were assumed to spend 8% of their time in the cottage area. Other PCGs are conservatively assumed to spend 100% of their time at their residence locations. Local food and water consumption rates were used based on the latest life style survey (CNL 2016b), and documented in the Performance Assessment (CNL 2017).

5.8.6.1.1.3 Contaminants

Table 5.8.6-2 displays the bounding estimate of radionuclide inventory in the ECM, which was used in the assessment of dose to ecological receptors (CNL 2017). This represents a bounding estimate of the ECM inventory for the total waste volume of the completed ECM (1,000,000 cubic metres [m^3]) used for assessment purposes. The inventory is a reference inventory based on the existing characterized waste streams, which forms a small portion of the overall inventory. This was extrapolated to 1,000,000 m^3 using expert opinion. While there is uncertainty with this data set, the waste quality and characterization program will assure the inventory envelope is not exceeded.

Table 5.8.6-2: Bounding NSDF Project Waste Radionuclide Inventory to be Placed in the Engineered Containment Mound

Radionuclide	Total Activity (Bq)	Radionuclide	Total Activity (Bq)
Ag-108m	2.03×10^{11}	Pu-239	2.01×10^{12}
Am-241	5.19×10^{13}	Pu-240	3.13×10^{12}
Am-243	1.97×10^{10}	Pu-241	1.02×10^{11}
C-14	4.41×10^{13}	Pu-242	9.37×10^{9}
Cl-36	1.93×10^{11}	Ra-226	5.79×10^{11}
Co-60	4.38×10^{15}	Se-79	2.16×10^{9}
Cs-135	6.63×10^{9}	Sn-126	3.16×10^{9}
Cs-137	5.31×10^{17}	Sr-90 + Y-90	1.66×10^{15}
H-3	4.82×10^{15} [(a)]	Tc-99	6.88×10^{12}
I-129	1.48×10^{12}	U-233	1.88×10^{10}
Mo-93	3.51×10^{7}	U-234	3.86×10^{12}
Nb-94	2.97×10^{13}	U-235	2.49×10^{11}
Ni-59	6.68×10^{10}	U-238	1.24×10^{13}
Ni-63	2.53×10^{13}	Zr-93	1.18×10^{13}

The inventory is a reference inventory based on the existing characterized waste streams, which form a small portion of the inventory. This was extrapolated to 1,000,000 m^3 using expert opinion. While there is uncertainty with this data set, the waste quality and characterization program will assure the inventory envelope is not exceeded.

The waste inventory was estimated based on radionuclide quantities in 2020.

a) Maximum tritium inventory placed within the ECM is estimated at 4.8×10^{15} Bq; however, waste streams with high tritium content will be placed in special packaging or decay-stored so that no more than 3.9×10^{13} Bq will be available for leaching prior to the ECM closure.

Bq = Becquerels

Radon emissions and tritium in leachate were estimated using RESidual RADioactivity (RESRAD) 3.1. The modelling scenario for the operations phase considered that there will be one active cell, partially filled with waste and the remaining cells will be either empty or filled with radioactive waste, and closed using an engineered cover.

Waterborne Effluent – Operations Phase

The total average annual volume of leachate, contact stormwater, and decontamination water under this operating scenario is 6,556 cubic metres per year (m^3/year). These maximum rates are calculated based on average annual precipitation, for a limiting condition in which one active cell is open and the remaining cells filled and closed. Treated effluent is discharged from the WWTP to an infiltration area ultimately leading to the East Swamp wetland. For the operations phase modelling, it is conservatively assumed that no dilution occurs prior to the East Swamp wetland. The annual average flow rate of the East Swamp stream, which drains the wetland, is 7.2×10^4 m^3/yr. Average annual outflow from this wetland is via East Swamp Stream to Perch Lake, which discharges to the Ottawa River via Perch Creek at 1.70×10^6 m^3/yr.

Treated effluent discharged to the infiltration area will contain small quantities of residual contaminants. Treated wastewater will enter the East Swamp stream, and proceed to Perch Lake, Perch Creek, and the Ottawa River as described above. The concentrations of radionuclides in the WWTP effluent are assumed to be equal to CNL's treatment targets, as presented in Table 5.8.6-3. This is a conservative assumption, as the majority of releases will be below these limiting values as a result of treatment. Also presented in Table 5.8.6-3 are concentrations of radionuclides in the East Swamp Stream. They were derived by applying a dilution factor of 12.5, which was calculated based on the flow rate of 72,000 m^3/y in the East Swamp stream and the WWTP effluent flow rate of 6,556 m^3/y.

Table 5.8.6-3: Maximum Concentrations of Radionuclides in the Treated Effluent and East Swamp Stream

Radionuclide	Concentration in Treated Effluent (Bq/L)[(b)]	Concentration in East Swamp Stream (Bq/L)
Ag-108m	60	5.0
Am-241	0.7	0.1
Am-243	0.7	0.1
C-14	200	16.7
Cl-36	100	8.3
Co-60	40	3.3
Cs-135	70	5.8
Cs-137	10	0.8
H-3[(a)]	1.4×10^5	1.2×10^4
I-129	1	0.1
Mo-93	40	3.3
Nb-94	80	6.7
Ni-59	2000	166.9
Ni-63	900	75.1
Np-237	1	0.1
Pu-239	0.6	0.1
Pu-240	0.6	0.1
Pu-241	0.6	0.1
Pu-242	0.6	0.1

Table 5.8.6-3: Maximum Concentrations of Radionuclides in the Treated Effluent and East Swamp Stream

Radionuclide	Concentration in Treated Effluent (Bq/L)[(b)]	Concentration in East Swamp Stream (Bq/L)
Ra-226	0.5	0.0
Se-79	50	4.2
Sn-126	30	2.5
Sr-90	5	0.4
Tc-99	200	16.7
U-233	3	0.3
U-234	3	0.3
U-235	3	0.3
U-238	3	0.3
Zr-93	5	0.4

a) To be determined. Tritium oxide (HTO) concentration in leachate, as presented in Table 5.7.6-2, was estimated based on the projected inventory of tritium in bulk waste. This does not account for waste, which may be placed into specialized containers, designed to minimize potential emissions of tritium, or decay-stored prior to placement into the ECM.

b) Discharge limit concentration, as an upper bound.

Bq/L = Becquerels per litre.

Waterborne Effluent – Post-Institutional Control Period

For the post-Institutional Control period (i.e., after year 2400), soil at the ECM may begin to erode and engineered barriers will deteriorate. Eventually, it is assumed that the waste, having dried out during the post-closure period of Institutional Control, will rehydrate and become partially saturated due to infiltration of precipitation through the deteriorated ECM cover. At this time, one of two plausible scenarios may take place:

- **Leaching Through the Base Liner:** If the base liner fails at this time, then it will provide a pathway for the leachate to enter the groundwater. The rate at which contaminants move through the liner system and the groundwater flow system will in part be controlled by the solubility and sorption interactions that involve specific contaminants. If sufficiently mobile, the contaminants will eventually discharge to Perch Creek and thence to the Ottawa River.
- **Bathtub Effect Overflow Scenario:** If the base liner remains intact, then the infiltrating water will continue to be constrained by the ECM liner and berms. Water will enter the ECM at a rate determined by the degree of failure of the cover and percolate through the waste. Within confines of the berms the ECM will become fully saturated and leachate will discharge to surface at the lowest point of the berm. Depending on the rate of discharge the escaping leachate will infiltrate to the local groundwater flow system and may also flow overland to Perch Creek.

Both of these scenarios are analyzed as "normal evolution" scenarios which may occur immediately following the end of institutional control in the year 2400.

The concentrations of radionuclides in ECM waste at year 2400 were estimated using RESRAD as shown in Table 5.8.6-4 and were used as the source term for the post-Institutional Control period groundwater transport scenario. These calculations account for radioactive decay and ingrowth (CNL 2017).

Table 5.8.6-4: Concentrations of Radionuclides in the Engineered Containment Mound at Year 2400

Radionuclide	Radionuclide Concentration (Bq/g)	Radionuclide	Radionuclide Concentrations (Bq/g)
Ac-227	6.70×10^{-4}	Pu-239	7.29×10^{-1}
Ag-108m	9.36×10^{-3}	Pu-240	1.11×10^{0}
Am-241	1.03×10^{0}	Pu-241	4.26×10^{-10}
Am-243	6.98×10^{-3}	Pu-242	3.44×10^{-3}
C-14	1.55×10^{1}	Ra-226	1.80×10^{-1}
Cl-36	7.07×10^{-2}	Ra-228	1.15×10^{-13}
Co-60	2.29×10^{-16}	Se-79	7.89×10^{-4}
Cs-135	2.43×10^{-3}	Sn-126	1.16×10^{-3}
Cs-137	3.00×10^{1}	Sr-90	7.18×10^{-2}
H-3	1.60×10^{-5}	Tc-99	2.52×10^{0}
I-129	5.43×10^{-1}	Th-228	1.13×10^{-13}
Mo-93	1.20×10^{-5}	Th-229	2.43×10^{-4}
Nb-93m	4.33×10^{0}	Th-230	4.86×10^{-3}
Nb-94	1.08×10^{1}	Th-232	1.20×10^{-13}
Ni-59	2.44×10^{-2}	U-233	6.89×10^{-3}
Ni-63	5.97×10^{-1}	U-234	1.42×10^{0}
Np-237	3.06×10^{-3}	U-235	9.12×10^{-2}
Pa-231	7.30×10^{-4}	U-236	1.27×10^{-5}
Pb-210	1.83×10^{-1}	U-238	4.55×10^{0}
Po-210	1.83×10^{-1}	Zr-93	4.33×10^{0}

Bq/g = Becquerels per gram.

The post-Institutional Control period groundwater transport scenarios utilized the following additional parameters and assumptions:

- The net infiltration rate through the ECM is 0.3 metres per year (m/yr), assuming a catastrophic failure of the multi-layered engineered cover.
- Effective porosity of the saturated zone is 0.3 with a hydraulic conductivity of 1.7×10^{-4} metres per day (5,400 m/yr) and hydraulic gradient of 0.007 metres (m). The depth of aquifer contributing to Perch Creek is 3 m. These parameters were derived based on site-specific parameters and adjusted by calibration to align with site-specific measurements and groundwater modelling results (Golder 2016).

- The longitudinal dispersivity of the saturated zone is 0.3 m (Indelman et al. 1999). No lateral dispersion is assumed. The latter is a conservative assumption reflecting a relatively short transport route to Perch Creek.
- Site specific distribution coefficients are used for aquifer and sediment. Standard values from CSA Standard N288.1-14 are used for representing retardation within the ECM (CNL 2017).
- No credit is taken for the loss of the inventory due to the release occurring prior to the end of institutional control. This is a conservative approach, maximizing the inventory available for leaching.
- The flow rate in the Perch Creek is 1.77×10^{6} m^3/yr (5-year average) (CNL 2016a).
- Future climate, hydrological, hydrogeological conditions are the same as at present time.
- Human habits, specifically local food and water consumptions, are unchanged from the current conditions as defined by the site specific lifestyle survey (CNL 2016b).

For the “Leaching through Base liner” scenario, the ECM cover and base liner are assumed to deteriorate, resulting in progressive infiltration of the cover resulting in water ingress in the waste. Contaminated leachate then enters the groundwater system, and contaminants are transported to Perch Creek and eventually flow to the Ottawa River. Waterborne emission rates from the ECM and contaminant transport into Perch Creek via groundwater were estimated using RESRAD OFFSITE. Biosphere modelling was conducted and doses to individual members of PCGs due to exposure to waterborne emissions from the NSDF were calculated using IMPACT 5.5.1.

For the “Bathtub Effect Overflow” scenario, the ECM cover is assumed to deteriorate while the base liner remains intact. As a result, water ingress causes the waste to become fully hydrated, with contaminated water eventually overtopping the ECM perimeter berm and leaching into the ground or surface water system. It was conservatively assumed to occur in the Year 2400 and that this contaminated water discharges directly into Perch Creek without any reduction in concentrations due to decay or dispersion. The resulting radionuclide flux in the overtopping leachate is calculated as shown in Table 5.8.6-5.

Table 5.8.6-5: Radionuclide Flux Flowing out of the ECM during Bathtub Scenario

Radionuclide	Radionuclide Concentrations (Bq/yr)	Radionuclide	Radionuclide Concentrations (Bq/yr)
Ac-227	1.07×10^{6}	Pu-239	2.14×10^{7}
Ag-108m	2.52×10^{6}	Pu-240	3.25×10^{7}
Am-241	7.77×10^{7}	Pu-241	1.25×10^{-2}
Am-243	5.25×10^{4}	Pu-242	1.01×10^{5}
C-14	2.48×10^{10}	Ra-226	3.07×10^{6}
Cl-36	3.71×10^{8}	Ra-228	1.95×10^{-6}
Co-60	1.16×10^{-8}	Se-79	1.16×10^{5}
Cs-135	2.12×10^{5}	Sn-126	8.32×10^{4}
Cs-137	2.62×10^{9}	Sr-90	3.36×10^{7}

Table 5.8.6-5: Radionuclide Flux Flowing out of the ECM during Bathtub Scenario

Radionuclide	Radionuclide Concentrations (Bq/yr)	Radionuclide	Radionuclide Concentrations (Bq/yr)
H-3	2.92×10^{6}	Tc-99	3.29×10^{11}
I-129	9.67×10^{8}	Th-228	2.03×10^{-7}
Mo-93	3.09×10^{3}	Th-229	4.37×10^{2}
Nb-93m	5.60×10^{7}	Th-230	8.73×10^{3}
Nb-94	1.39×10^{8}	Th-232	2.15×10^{-7}
Ni-59	5.63×10^{6}	U-233	7.19×10^{5}
Ni-63	1.38×10^{8}	U-234	1.48×10^{8}
Np-237	3.93×10^{6}	U-235	9.51×10^{6}
Pa-231	1.31×10^{4}	U-236	1.32×10^{3}
Pb-210	5.90×10^{7}	U-238	4.75×10^{8}
Po-210	5.81×10^{8}	Zr-93	2.80×10^{7}

Bq/yr = Becquerels per year.

Airborne Releases – Operations Phase

During operations, the ECM may emit airborne radionuclide releases. Potential discharges include emissions of radioactive dust during handling of bulk materials and gaseous emissions during storage and disposal of radioactive materials. The expected gaseous radionuclide releases are:

- tritium in the form of tritium oxide (HTO);
- gases containing C-14; and,
- Radon (Rn-222) will additionally be released due to the decay of Ra-226, Pu-242, U-234, and U-238.

Emission rates of tritium and carbon-14 were estimated based on empirical ratios between radionuclide content in the waste and releases (OPG 2011):

- HTO: 1% of the inventory per year, based on historical operational data;
- C-14: 0.07% of the inventory per year, based on historical operational data; and,
- Rn-222: evaluated using RESRAD Offsite software, based on ingrowth in the disposed waste and migration through the waste material. The methodology is described in Appendix C of the user's manual for RESRAD (onsite; Argonne National Laboratory 2001).

The contribution from fugitive emissions is considered to be negligible in comparison to ECM releases. Resulting airborne emission rates are displayed in Table 5.8.6-6.

Table 5.8.6-6: Airborne Emission Rates from the Engineered Containment Mound during Operations

Radionuclides	Airborne Emission Rate (Bq/s) at Year 2070
H-3	1.24×10^{4}
C-14	9.79×10^{2}
Rn-222	4.17×10^{-3}

Note: Radon dose is very minor given its low emission rate and therefore is not considered further.
Bq/s = bequerels per second.

After closure of the ECM, the installation of the engineered cover and decay of radionuclides will result in lower gaseous discharges. Therefore, gaseous emissions during the post-closure phase are bounded by those during the operational phase. For this reason, only the gaseous emissions and dose resulting from the operations phase are assessed.

5.8.6.1.1.4 Exposure Pathways

The exposure pathways considered for the assessment of radiological dose to human receptors is consistent with CSA Standard N288.1-14 (CSA 2014). This includes the assessment of the following exposure pathways:

- air inhalation/skin absorption;
- air immersion (external exposure);
- water ingestion;
- water immersion (via swimming or bathing);
- soil external exposure;
- soil ingestion (incidental);
- terrestrial plant ingestion;
- terrestrial animal ingestion;
- aquatic plant ingestion;
- aquatic animal ingestion;
- sediment external exposure; and,
- sediment ingestion (incidental).

The radiological dose to human receptors as a result of airborne and liquid effluent releases and subsequent environmental transport according was calculated using IMPACT 5.5.0 modelling software. This software calculates dose arising from all atmospheric and aquatic pathways described in CSA Standard N288.1-14, as shown in Figure 5.8.6-1.

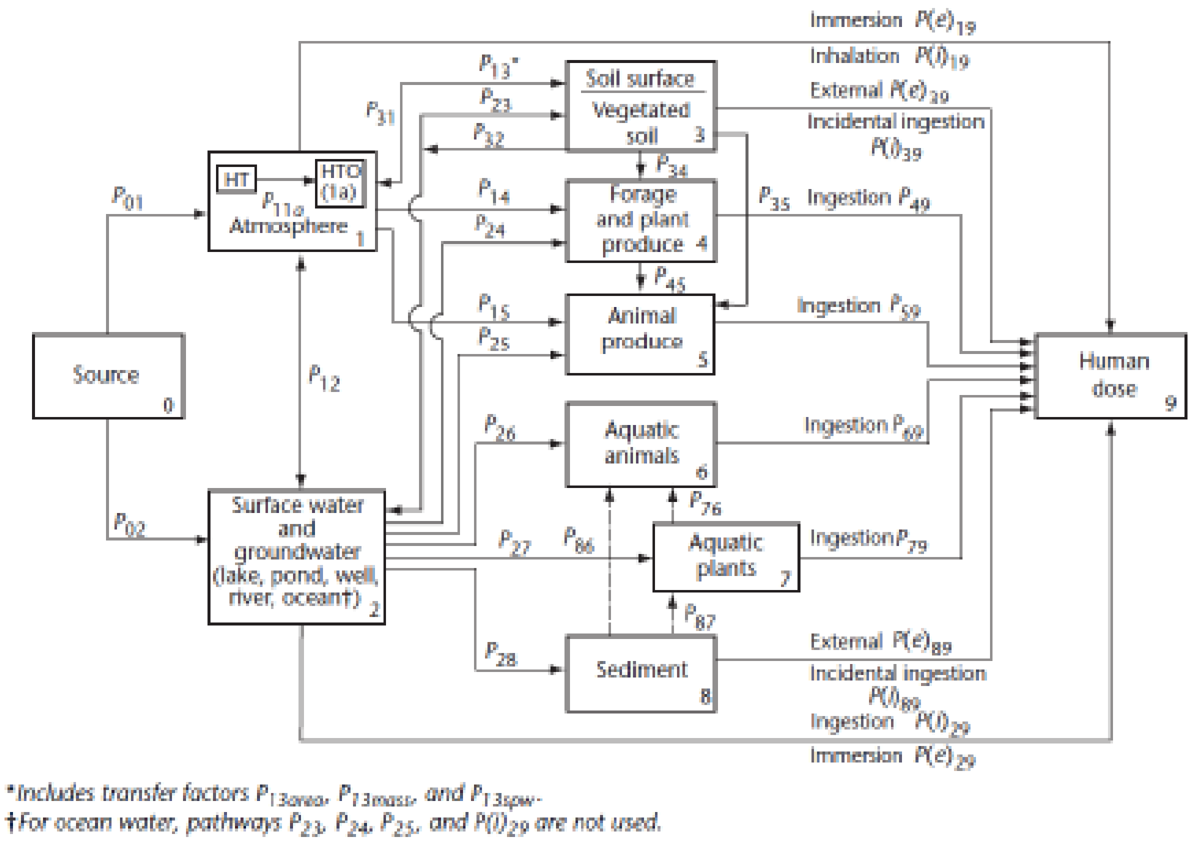


Figure 5.8.6-1: Generalized Model of Environmental Radioactivity Transport and Human Exposure Pathways (CSA 2014)

Factors influencing human exposure, including occupancy factors, water supply assumptions, food sources, and intake rates, followed those used in the CRL Derived Release Limits report (AECL 2011), with modifications made as discussed in the Performance Assessment (CNL 2017). The pathways and radionuclides are different from current CRL operations they consider a different set of emissions. In the case of NSDF operations emissions to air are limited to HTO and C-14. Furthermore, the assessment used the latest (2016) set of habits and consumption rates, which also has an effect when comparing to CRL's annual reports.

5.8.6.1.2 Application Case Results

The dose to potential critical groups arising from waterborne and airborne emissions during NSDF operations are shown in Table 5.8.6-7 and Table 5.8.6-8, respectively. Total doses arising from the NSDF Project during the operations phase are shown in Table 5.8.6 9 and Table 5.8.6-10.

Table 5.8.6-7: Doses to Potential Critical Groups Due to Exposure to Waterborne Emissions during Operations

Receptors	Dose to Adult (µSv/yr)	Dose to 10 year old Child (µSv/yr)	Dose to one year old Infant (µSv/yr)
Cottager	4.3×10^{-5}	4.3×10^{-5}	2.4×10^{-5}
Pembroke	8.1×10^{-4}	8.1×10^{-4}	1.1×10^{-3}
Petawawa	8.8×10^{-4}	8.9×10^{-4}	1.2×10^{-3}
Laurentian Valley	8.1×10^{-4}	8.1×10^{-4}	1.1×10^{-3}

µSv/yr = microsieverts per year.

Table 5.8.6-8: Doses to Potential Critical Groups Due to Exposure to Airborne Emissions during Operations

Receptors	Dose to Adult (µSv/yr)	Dose to 10 year old Child (µSv/yr)	Dose to one year old Infant (µSv/yr)
Balmer Bay	7.3×10^{-3}	8.8×10^{-3}	1.3×10^{-2}
Chalk River	6.9×10^{-3}	1.1×10^{-2}	2.1×10^{-2}
Cottager	6.5×10^{-3}	5.6×10^{-3}	5.7×10^{-3}
Deep River	3.1×10^{-3}	5.5×10^{-3}	1.1×10^{-2}
Mountainview	3.4×10^{-3}	5.8×10^{-3}	1.1×10^{-2}
Pembroke	4.2×10^{-4}	6.6×10^{-4}	1.2×10^{-3}
Petawawa	3.3×10^{-4}	5.9×10^{-4}	1.2×10^{-3}
Laurentian Valley	4.3×10^{-4}	6.5×10^{-4}	1.2×10^{-3}

µSv/yr = microsieverts per year.

Table 5.8.6-9: Total Doses to Potential Critical Groups during Operations

Receptors	Dose to Adult (µSv/yr)	Dose to 10 year old Child (µSv/yr)	Dose to one year old Infant (µSv/yr)
Balmer Bay	7.3×10^{-3}	8.8×10^{-3}	1.3×10^{-2}
Chalk River	6.9×10^{-3}	1.1×10^{-2}	2.1×10^{-2}
Cottager	6.6×10^{-3}	5.6×10^{-3}	5.8×10^{-3}
Deep River	3.1×10^{-3}	5.5×10^{-3}	1.1×10^{-2}
Mountainview	3.4×10^{-3}	5.8×10^{-3}	1.1×10^{-2}
Pembroke	1.2×10^{-3}	1.5×10^{-3}	2.3×10^{-3}
Petawawa	1.2×10^{-3}	1.5×10^{-3}	2.4×10^{-3}
Laurentian Valley	1.2×10^{-3}	1.5×10^{-3}	2.3×10^{-3}

µSv/yr = microsieverts per year.

Table 5.8.6-10: Total Doses to Hypothetical Groups Using Water from the Perch Creek Outfall during Operations

Receptors	Dose to Adult (µSv/yr)	Dose to 10 year old Child (µSv/yr)	Dose to one year old Infant (µSv/yr)
Balmer Bay	2.1×10^{-2}	2.4×10^{-2}	2.7×10^{-2}
Chalk River	2.1×10^{-2}	2.2×10^{-2}	2.7×10^{-2}
Deep River	2.0×10^{-2}	2.3×10^{-2}	2.6×10^{-2}
Mountain View	1.9×10^{-2}	2.1×10^{-2}	2.2×10^{-2}

µSv/yr = microsieverts per year.

The maximum estimated dose to PCGs (0.021 microsieverts per year [µSv/yr]) is to the Chalk River infant. This represents less than 0.01% of the regulatory dose limit of 1 mSv/yr and licensing limit of 0.3 mSv/yr. The major dose contributor to the critical group exposure (infant at Chalk River) is C-14 and the dominant pathway is consumption of terrestrial animal and product- milk. Based on the available data it was conservatively assumed that 100% of milk consumption was from the local sources. Doses to the hypothetical groups are in the range of 190 µSv/y to 270 µSv/y. This is less than the regulatory dose limit of 1 mSv/y and CNL's licensing limit of 0.3 mSv/y.

The Balmer Bay, Chalk River, Cottager, Deep River, and Mountainview PCGs receive the majority of their dose through airborne emissions, due to their closer proximity to the NSDF site. The Pembroke, Petawawa, and Laurentian Valley receptors receive the majority of their dose from waterborne emissions. The main dose contributor to the critical group exposure (infant at Petawawa) is Ag-108m and the dominant pathway is external exposure to sediment.

Doses to PCGs as a result of groundwater transport in the post-Institutional Control period of the NSDF are shown in Table 5.8.6-11 and Table 5.8.6-12. As described in Section 5.8.6.1.1.3, dose to PCGs from airborne emissions in the post-Institutional Control period are bound by those which arise during the operational phase (shown in Table 5.8.6-6).

Table 5.8.6-11: Doses to Potential Critical Groups Due to Exposure to Waterborne Emissions during the Post-Institutional Control "Leaching through Base Liner" Scenario

Receptors	Dose to Adult (µSv/yr)	Dose to 10 year old Child (µSv/yr)	Dose to one year old Infant (µSv/yr)
Cottager	5.7×10^{-4}	5.6×10^{-4}	6.0×10^{-4}
Pembroke	4.2×10^{-2}	7.5×10^{-2}	1.4×10^{-1}
Petawawa	3.9×10^{-2}	7.3×10^{-2}	1.4×10^{-1}
Laurentian Valley	3.8×10^{-2}	7.1×10^{-2}	1.4×10^{-1}

µSv/yr = microsieverts per year.

The maximum estimated dose to PCGs (0.14 µSv/yr) during the post-Institutional Control period is to the Pembroke and Petawawa infant. The peak is predicted to occur approximately 150 years after the end of Institutional Control and failure of the engineered cover. This amounts to 0.02% of the regulatory dose limit of 1 mSv/yr and 0.05% of the CRL site dose constraint of 0.3 mSv/yr.

Table 5.8.6-12: Doses to Potential Critical Groups due to Exposure to Waterborne Emission for the Post-Institutional Control "Bathtub" Scenario

Receptors	Dose to Adult (µSv/yr)	Dose to 10 year old Child (µSv/yr)	Dose to one year old Infant (µSv/yr)
Cottager	2.6×10^{-3}	2.5×10^{-3}	1.8^{-3}
Pembroke	8.7×10^{-2}	1.3×10^{-1}	2.1^{-1}
Petawawa	8.8×10^{-2}	1.3×10^{-1}	2.1^{-1}
Laurentian Valley	7.0×10^{-2}	1.1×10^{-1}	2.0^{-1}

µSv/yr = microsieverts per year.

The maximum estimated dose to PCGs (0.21 µSv/yr) during the post-Institutional Control period for the "Bathtub" scenario is to the Pembroke infant. This is 0.02% of the regulatory dose limit of 1 mSv/yr and 0.07% of the CRL site dose constraint of 0.3 mSv/yr.

5.8.6.2 Non-radiological Exposure Assessment

5.8.6.2.1 Application Case Methods

The non-radiological exposure assessment considered the following four scenarios for the surface water environment: (described in Section 5.4.2.6.1.2):

- Scenario 1 (operational phase years 2020 to 2025): the ECM is defined as one single active cell where leachate effluent is discharged to an infiltration area (i.e., upstream of the East Swamp Weir) after treatment at the WWTP.
- Scenario 2 (operational phase years 2065 to 2070): the ECM is operating with multiple active and closed cells (six closed, three interim cells, and one active cell) with the base liner intact and leachate being discharged after treatment at the WWTP.
- Scenario 3 (post-closure phase after year 2100): all ten cells of the ECM are closed with the cover intact and the WWTP decommissioned (i.e., discharge of untreated effluent).
- Scenario 4 (post-Institutional Control phase after year 2400): bathtub effect occurs with spill-over along the southern border of the ECM due to degradation and inevitable failure of the cover.

The four surface water model scenarios were completed for a select group of parameters termed constituents of potential concern (COPCs) as defined in Section 5.4.2.6.3. Key elements of the COPC selection process included identifying those parameters that were expected to change as a result of the NSDF Project, those with available guidelines, and those that were expected to be toxic to aquatic organisms. The ten selected COPCs were aluminum, barium, cadmium, copper, iron, lead, manganese, mercury, phosphorus and zinc.

A preliminary screening was completed as shown in Section 5.4.2.6.3, wherein predicted concentrations of parameters in untreated effluent were compared to treatment targets. The treatment targets (see Table 5.4.2-6) are generally based on aquatic guidelines from a variety of sources including Canadian Council of Ministers of the Environment (CCME), United States Environmental Protection Agency (U.S. EPA), United States Department of Energy (U.S. DOE), and others. However, to ensure that human health is adequately protected, predicted concentrations of non-radiological parameters were compared to federal guidelines that are

protective of human health. Where federal guidelines were not available, provincial guidelines that are similarly protective of human health were consulted. In the absence of both federal and provincial guidelines, alternate guidelines from other jurisdictions were used. The selected guidelines are described below.

It is noted that the air quality discipline assessed the predicted non-radiological concentrations in air emissions during the operations phase of the Project; the concentrations of the modelled parameters are below applicable air quality guidelines and/or standards (see Section 5.2.1.6.2) and such were not considered further for human health.

5.8.6.2.1.1 Guidelines

Federal Guidelines

The federal guidelines include those published by the CCME and Health Canada:

- The Health Canada Guidelines for Canadian Drinking Water Quality (CDWQ) are based on health effects, aesthetic effects and operational considerations for drinking water (Health Canada 2014). Health-based standards are listed as maximum acceptable concentrations and are established based on comprehensive review of known health effects, exposure levels and the availability of treatment and analytical technologies. If no health-based standard was available for a given chemical, then an aesthetic objective or operational guideline was used. Aesthetic objectives (i.e., taste and odour) are established based on whether people will consider the water drinkable. Operational guideline values are established based on levels that may interfere or impair water treatment processes or technology or adversely affect drinking water infrastructure.

Provincial Guidelines

The provincial guidelines include those published by the Ontario Ministry of the Environment and Climate Change (MOECC), formerly the Ontario Ministry of the Environment and Energy (MOEE) and the Ontario Ministry of the Environment (MOE):

- The MOEE Provincial Water Quality Objectives (PWQOs) are intended to be protective of aquatic life and recreational uses of surface waters (MOEE 1994). The PWQOs represent a desirable level of water quality strived to be maintained in the province. While these objectives are intended for protection of aquatic life, it is considered that they are also protective of human and wildlife health because PWQOs are typically much lower than drinking water guidelines and livestock watering guidelines.

- The primary purpose of the Government of Ontario Regulation (O. Reg.) 169/03 Ontario Drinking Water Standards (ODWS) is to protect public health through the provision of safe drinking water (MOE 2002). The standards are protective against unsafe concentrations of toxic metals, radioactive substances and disease-causing organisms. Like the drinking water quality standards from Health Canada (i.e., CDWQ), ODWS are presented as maximum acceptable concentrations above which there are known or suspected adverse health effects. Standards can also be based on aesthetic objectives, including taste, odour, turbidity and colour, or operational guidelines, including corrosiveness.

Alternate Guidelines

For parameters for which federal and/or provincial guidelines were not health-based (i.e., operational guidelines [OG] or aesthetic objectives [AO] from Health Canada or based on aquatic life for the PWQOs), alternate guidelines were also considered. Alternate guidelines were sourced from the U.S. EPA (United States Environmental Protection Agency). The U.S. EPA provides a similar level of review of the available scientific literature and a similar approach to setting water quality guidelines as Health Canada and Ontario to be protective of human health and the environment. The selected health-based guidelines are shown below in Table 5.8.6-13.

Table 5.8.6-13: Selection of Health-Based Guidelines for Non-Radiological Parameters in Surface Water

Parameter	Federal Guidelines	Provincial Guidelines		Alternate Guidelines
	Health Canada[a]	PWQO[b]	ODWS[c] or GW1[d]	U.S. EPA Tap Water[e,f]
Aluminum	100 (OG)	15	NV	4,000
Barium	1,000	NV	NV	760
Cadmium	5.0	0.5	NV	1.8
Copper	1,000 (AO)	1	NV	160
Iron	300 (AO)	300	NV	2,800
Lead	10	1	NV	15 (MCL)
Manganese	50 (AO)	NV	NV	86
Mercury	1.0	0.2	NV	1.1
Phosphorus	NV	10	NV	NV
Zinc	5,000 (AO)	30	NV	1,200

Notes:

Selected health-based guidelines are shown with gray shading.

a) Health Canada. 2014. Guidelines for Canadian Drinking Water Quality – Summary Table. Water, Air and Climate Change Bureau, Health Environments and Consumer Safety Branch, Health Canada, Ottawa, Ontario.

b) MOEE. 1994. Provincial Water Quality Objectives (PWQOs).

c) MOE. 2002. Ontario Regulation (O.Reg.) 169/03 Ontario Drinking Water Standards (ODWS) under *Safe Drinking Water Act, 2002, S.O. 2002, c. 32*.

d) MOE. 2011. Rationale for the Development of Soil and Ground Water Standards for Use at Contaminated Sites. Standards Development Branch. Toronto, ON.

e) U.S. EPA. 2016. Regional Screening Levels – Generic Tables (May 2016). [Updated May 2016; Accessed November 2016].https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables-may-2016.

f) The U.S. EPA Tap Water Regional Screening Levels (RSLs) were derived considering a target Hazard Quotient (HQ) of 0.1 and Incremental Lifetime Cancer Risk of 1x10-6. The values presented in this table reflect a target HQ of 0.2 (to be consistent with Ontario).

PWQO = Ontario Provincial Water Quality Objective; ODWS = Ontario Drinking Water Standard; GW1 = Groundwater component value protective of drinking by humans; U.S. EPA = United States Environmental Protection Agency; NV = No Value.

The selected health-based guidelines are considered to be protective of members of the public (including sensitive receptors such as the very young, elderly, women of child-bearing age, and those with pre-existing conditions) that rely on surface water for drinking and bathing. For the purposes of this assessment, it has been assumed that there are no restrictions on members of the public obtaining their potable water from the surface water nodes that may be affected by the Project during the operations, post-closure and post-institutional phases. This is a conservative assumption when considering the operations phase because no water intakes are known to exist in any of the affected water bodies and none of the areas around the water bodies are populated. It was also determined in Section 5.4.2 that the assimilative capacity of the Ottawa River (in which there are water intakes) is sufficient at diluting concentrations to below the treatment targets for the selected modeled parameters. However, it is unknown whether cottages or homes may be built along these water bodies in the far future (i.e., post-closure or post-institutional control phases when the water treatment plant has been decommissioned). Therefore, while the guidelines are likely overly conservative for the operations phase, the degree of uncertainty is unknown for the post-closure and post-institutional control phases given the uncertainty in use of the affected surface water bodies during those Project phases.

5.8.6.2.2 Application Case Results

The predicted non-radiological concentrations of the ten selected POPCs at six water quality nodes for four scenarios are provided in Section 5.4.2.6.4.1 (Tables 5.4.2-8 to Table 5.4.2-17). The predictions were compared to treatment targets and to local background at the six water quality nodes; the predicted concentrations of lead, phosphorus and zinc met their respective treatment targets and local background concentrations and as such were not retained for further consideration.

Comparison of the predicted concentrations of aluminum, barium, cadmium, copper, iron, manganese, and mercury to the selected health-based guidelines is shown in Table 5.8.6-14 below.

Table 5.8.6-14: Comparison of Health-Based Guidelines to Maximum Predicted Surface Water Concentrations for each Parameter for All Modelled Scenarios and Locations

Parameter	Health-Based Guidelines (µg/L)	Maximum (µg/L)	Scenarios with Exceedances	Locations with Exceedances
Aluminum	4,000	129	None	None
Barium	760	86.8	None	None
Cadmium	1.8	0.8	None	None
Copper	160	8.6	None	None
Iron	2,800	6,930	Scenario 3 Scenario 4	ESW (95th and max) PCW, PCO (all stats)
Manganese	86	280	Scenario 4	PCW, PCO (all stats)
Mercury	1.0	0.63	None	None

The predicted concentrations for all modelled parameters for Scenarios 1 and 2 (i.e., operations phase when leaching will be treated at the WWTP prior to discharge) met their respective health-based guidelines. Therefore, there are no anticipated risks to human health due to the modeled non-radiological parameters during the operations phase of the Project. The maximum predicted iron and manganese concentrations at select nodes were greater than their respective health-based guidelines during the post-closure (Scenario 3) and post-institutional control (Scenario 4) phases of the Project, which follow the decommissioning of the WWTP.

Considering the conservative assumptions related to the non-radiological concentrations in the waste material and the conservative assumptions in the water quality modelling (Section 5.4.2), and considering that wastes will be required to meet the facility's Waste Acceptance Criteria, risks associated with these parameters and phases are likely negligible. Therefore, with additional information related to water hardness, risks associated with these parameters and phases can be refined.

5.8.7 Prediction Confidence and Uncertainty

Table 5.8.7-1 describes key uncertainties in assessing residual effects from the NSDF Project on human health and how conservatism in the analysis and assumptions addressed these uncertainties.

Table 5.8.7-1: Uncertainties in the Human Health Assessment

Parameter	Uncertainty	Conservatism and Assumptions
Waste Inventory	There is uncertainty with regards to the inventory of radionuclides that have been accumulated over the decades of operation of CRL site, as well as the projected inventory of wastes that will be generated in the future.	■ Estimates of the total ECM inventory where made conservatively using available data on wastes that are currently stored at CRL site. ■ Both already accumulated wastes and those that will be generated in the future will have to meet NSDF Waste Acceptance Criteria (WAC).
Waste Inventory	There is uncertainty with regards to the inventory of hazardous wastes (i.e., non-radionuclides) that have been accumulated over the decades of operation of the CRL site, as well as the project inventory of hazardous wastes (i.e., non-radionuclides) that will be generated in the future.	■ Both already accumulated wastes and those that will be generated in the future will have to meet NSDF Waste Acceptance Criteria (WAC). ■ Quantitative information is not available for hazardous wastes (i.e., non-radionuclides) in the materials to be placed in the NSDF. ■ In the absence of quantitative information, non-radioactive waste constituents were developed from information gathered from other sites and the expected characteristics of wastes to be disposed of in the NSDF. These values present a reasonable and conservative estimate of concentrations in wastewater such that the WWTP design is capable of treating wastewater to meet applicable surface release limits

Table 5.8.7-1: Uncertainties in the Human Health Assessment

Parameter	Uncertainty	Conservatism and Assumptions
ECM Performance	There is uncertainty with regards to when protective barriers may begin to fail due to erosion or other natural events.	■ The ECM includes multiple protective barriers in the cover and base liner, designed to isolate the waste even in the event if one or more of the barriers were to fail. ■ The ECM can be maintained and monitored during the period of institutional control. Any issues identified during this period can be mitigated. ■ Two conservative scenarios involving major failures of the cover and base liner were considered. It was assumed that the failure of the liner and cover would occur immediately following the end of institutional control. Predicted radiological doses to the public are an insignificant fraction of the regulatory limit and CNL's licensing limit. Iron and manganese were considered to pose a potential risk to the public; however, wastes will have to meet NSDF Waste Acceptance Criteria (WAC), which will be derived such that failure of the ECM would not result in detrimental effects to the environment or human health.
Source term	There is uncertainty associated with airborne and groundwater release rates.	■ Waterborne releases from the WWTP are assumed to contain contaminants at maximum permissible concentrations. This is a bounding assumption; in most cases concentrations will be a minor fraction of maximum permissible concentrations. ■ Airborne releases from the ECM are based on empirical data for C-14 and HTO and on a conservative model for Radon. The estimates neglect loss of contaminants over time, and decay as they migrate through the cover of capped cells.
Human habits	It is uncertain that future populations will maintain current habits, consumption rates, and that the location of population centers will not change.	■ Normal Evolution scenario assumed that the current habits are maintained in the future. ■ To investigate sensitivity to changes in future human habits and location of potential exposure groups, several additional scenarios are considered in the PA (CNL 2017).
Conceptual model	This uncertainty is associated with conceptual model for groundwater flow and potential future impacts on it resulting from the climate change	■ Current groundwater flow and contaminant transport in Perch Lake area are well understood due to decades of data available for the site. ■ Groundwater flow model was calibrated against the available datasets based on the existing plumes emanating from Waste Management Areas (WMA) and Liquid Dispersal Areas (LDA). ■ For the "Bathtub" scenario, it was conservatively assumed that overtopping of contaminated leachate, results in an instantaneous discharge into Perch Creek. This provides a limiting assumption for any future changes that may occur which may influence environmental transport parameters.

Table 5.8.7-1: Uncertainties in the Human Health Assessment

Parameter	Uncertainty	Conservatism and Assumptions
Assessment of radiological doses to members of the public	There is uncertainty in modelling parameters used for the assessment of radiological dose to members of the public	■ Conservative assumptions for dispersion and consumption rate parameters based on the DRL model for CNL site. Atmospheric dispersion and radiological doses to the public are evaluated in accordance with CSA N288.1, which provides a model based on conservative values for food, water, soil, and air intake rates for the representative person, typically at the 95th percentile level. Conservative values are also chosen for occupancy and other exposure factors. ■ Estimated radiological doses represent a very minor fraction of the limit.
Leaching and Transport parameters	Parameter uncertainty may lead to underestimation of radiological doses to members of the public and non-human biota	■ The site characteristics are well understood thanks to many decades of monitoring. In any case, conservative and bounding assumptions were used as described above. ■ Use of conservative values for sensitive parameters. A lower K_d for leaching from the ECM was considered in one of the sensitivity scenarios.
Impact of Environment on ECM	Performance of the ECM barriers could be impeded by natural events, such as floods, weathering, animal borrowing, and fires destroying vegetative cover.	Normal Evolution scenarios conservatively assumed failures of the cover and base liner immediately following the end of Institutional Control.
Modelling Tool uncertainty	Uncertainty associated with conceptual models built within RESRAD and IMPACT codes	■ Numerical uncertainty in the selected models has been evaluated through model validation. Model validation answers the question “Does the model accurately simulate the behaviour of the system?” Both RESRAD and IMPACT codes have undergone extensive validation for the pathways and exposure scenarios considered in the analysis. ■ Canadian Nuclear Safety Commission G-320 (CNSC 2006) acknowledges that uncertainty exists in modelling, and states that the reliability of long-term quantitative predictions diminishes with increasing timescale. Long term quantitative predictions should therefore not be considered as guaranteed impacts, but rather as safety indicators. It is also stated that uncertainties in modelling should be addressed by conservatism built into the assessment model, scenario design, and parameter choice. This is consistent with the manner in which this analysis has used long-term quantitative predictions of peak dose to PCGs in the post-institutional control period. As documented within this table, modelling uncertainty is addressed with conservatism built into the model, scenario design, and parameters.
Cumulative Effect	Uncertainty associated with the cumulative effect during post-closure, taking into account releases from WMAs and LDAs in the Perch Creek Basin.	■ Canadian Nuclear Laboratories is developing an appropriate environmental remediation concept for contaminated areas. The decision-making process is based on radiological impacts. ■ It is expected that, if there is any potential to have cumulative effects exceeding safety objectives, then contaminated land from WMAs and LDAs will be removed prior to the NSDF closure.

5.8.8 Residual Effects Classification and Determination of Significance

The residual effects analysis methods for the human health assessment are different in some notable ways from those used by other VCs. Specifically, the assessment of potential effects to human health VCs results in the generation of risk factors that inherently consider the geographic extent, duration, frequency and other characteristics of the predicted changes to the environment that may result from Project activities. As such, these inherent attributes cannot be used to determine environmental significance, as they can with other components. Instead, significance for human health is evaluated based on: (i) the potential magnitude of the response, as indicated by the comparison to benchmarks, and (ii) the degree of conservatism and uncertainty in the analysis.

Results of the radiological dose assessment for the operations phase and post-Institutional Control period indicates that doses to human health VCs are below their respective benchmark values. In addition, all predicted non-radiological concentrations were less than their selected guidelines or alternate benchmarks. Although uncertainties in the assessment exist (Section 5.7.7), conservatism has been included in the modelling so that residual effects are not greater than predicted. As such, residual effects are considered to be not significant for all human health VCs during the operations phase and the post-Institutional Control period.

5.8.9 Monitoring and Follow-up

Monitoring of environmental media at the CRL site and surrounding area will proceed as described in CNL's ongoing Environmental Monitoring Program (CNL 2016a). This includes sampling and analysis of surface water, groundwater, sediment, soil, vegetation, ambient air, milk, garden produce, game animals, farm animals, and fish. Section 5.7.4 provides additional details regarding the scope of these programs for monitoring radioactivity in environmental media.

Emissions and effluents from the NSDF Project during the construction, operations, closure, and post-closure phases will be managed in accordance with CNL's procedure Management and Monitoring of Emissions. This procedure defines the key requirements, responsibilities, and processes for the management of radioactive and non-radioactive emissions at the NSDF. The Environmental Protection Plan prepared for the NSDF Project expands on the regulatory requirements of CSA N288.5 for the management of these emissions. For example, operational control monitoring will be completed to confirm emission controls and treatment systems are functioning as intended. In addition, effluent monitoring will be completed to verify that emissions meet treatment targets.

An effluent verification monitoring program (EVMP) will be established for the monitoring of radioactive and non-radioactive emissions estimated from the NSDF Project. The EVMP at the NSDF Project is required to demonstrate compliance with the CRL public dose limit of 0.3 mSv, as well as the effective dose limit of 1 mSv/yr for members of the public established by the *Nuclear Safety and Control Act*.

5.8.10 Conclusions

Valued components refer to environmental features that may be affected by a project and that have been identified to be of concern by the proponent, scientists, government agencies, First Nation and Métis peoples, or the public (the Agency 2014). The human health risk assessment focused on worker and public health. Assessment endpoints are qualitative expressions used to assess the significance of residual effects on VCs and represent the key properties of the VC that should be protected for future human generations (i.e., incorporates sustainability). The assessment endpoint is the protection of human health. Measurement endpoints represent properties of the environment, that when changed, could result in or contribute to an effect on an assessment endpoint. Measurement endpoints for the human health assessment include changes in air quality, groundwater quality, and surface water quality.

Radiological dose to humans may result from waterborne or airborne emissions from the NSDF Project. Dose to humans from waterborne emissions is calculated during the operations phase, as well as during the post-Institutional Control period for the NSDF Project. Dose to humans from airborne emissions is calculated only for the operations phase of the NSDF. This represents the bounding case, since it is expected that doses to humans during the post-closure would be less than the operations phase with the installation of the final cover.

The maximum estimated dose to PCGs during NSDF operations is 0.021 µSv/y. This represents less than 0.01% of the regulatory dose limit of 1 mSv/y and licensing limit of 0.3 mSv/y. The Balmer Bay, Chalk River, Cottager, Deep River, and Mountainview PCGs receive the majority of their dose through airborne emissions, due to their closer proximity to the NSDF site. The Pembroke, Petawawa, and Laurentian Valley receptors receive the majority of their dose from waterborne emissions. The maximum estimated dose to PCGs during the post-Institutional Control period is 0.21 µSv/y. This represents 0.02% of the regulatory dose limit of 1 mSv/y and 0.07% of the licensing limit of 0.3 mSv/y.

Non-radiological chemicals were screened by comparing concentrations to the federal guidelines that are protective of human health. The predicted concentrations for all modelled parameters for Scenarios 1 and 2 (i.e., operations phase when leachate will be treated at the WWTP prior to discharge) met their respective health-based guidelines. Therefore, there are no anticipated risks to human health due to the modeled non-radiological parameters during the operations phase of the Project.

The maximum predicted iron and manganese concentrations at select nodes were greater than their respective health-based guidelines during the post-closure (Scenario 3) and post-institutional control (Scenario 4) phases of the Project, which follow the decommissioning of the WWTP. However, considering the conservative assumptions related to the non-radiological concentrations in the waste material and the conservative assumptions in the water quality modeling (Section 5.4.2), and considering that wastes will be required to meet the facility's Waste Acceptance Criteria, risks associated with these parameters and phases are likely negligible.

Although uncertainties in the assessment exist, conservatism has been included in the modelling so that residual effects are not greater than predicted. As such, residual effects are considered to be not significant for all human health VCs during the operations phase and the post-Institutional Control period. Monitoring and follow-up programs are described in Section 5.8.9 and include implementation of CNL's existing Environmental Monitoring Program and EVMP, as well as NSDF-specific environmental monitoring activities. These activities will verify effects predictions for human health.

This page intentionally left blank

5.9 Land and Resource Use

Section 5.9 of the Environmental Impact Statement (EIS) for the Canadian Nuclear Laboratories (CNL) Near Surface Disposal Facility (NSDF) Project seeks to understand and characterize the potential residual effects of the NSDF Project and past, present, and reasonably foreseeable developments on land and resource use. Land and resource assessment considers outdoor recreation and tourism, land tenure, archaeology, and traditional land and resource use by First Nation and Métis communities.

The assessment of effects on land and resource identifies linkages between the Project activities and current environment to determine the residual effects of the Project on land and resource use. Residual effects (i.e., those effects remaining after the implementation of all mitigation) are placed in context of the cumulative effects of previous, existing and future projects.

5.9.1 Scope of the Assessment

The CNSC's *Generic Guidelines for the Preparation of an Environmental Impact Statement* (CNSC 2016) identifies that the proponent is expected to consider the effects that are likely to arise from the project (including situations not explicitly identified in these guidelines), the technically and economically feasible mitigation measures that will be applied, and the significance of any residual effects. It identifies that "the proponent has the discretion to select the most appropriate methods to compile and present data, information and analysis in the EIS as long as the methods are transparent, justifiable and replicable" (CNSC 2016). To achieve these objectives, the land and resource use assessment follows the overall environmental assessment approach and methods described in Section 5.1. The assessment is completed in the following key steps:

- **Step 1 – Identify Valued Components (VCs) and define the spatial boundaries, temporal boundaries, and assessment cases** for the land and resource use assessment (refer to Sections 5.9.2 Valued Components and Section 5.9.3 Assessment Boundaries). The VCs, assessment endpoints, and measurement indicators used to assess NSDF Project related changes to land and resource use environment; the spatial and temporal boundaries at which the assessment occurred; and, the assessment cases considered.
- **Step 2 – Describe the existing conditions** (refer to Section 5.9.4 Description of the Environment). Existing conditions in the local and regional areas are described, including the combined effects of previous and existing developments (Base Case). The existing environment represents the historical and current environmental pressures that have shaped the observed patterns in the environment (i.e., natural variation).
- **Step 3 – Evaluate Project interactions and mitigation** (refer to Section 5.9.5 Project Interactions and Mitigation). Project components and/or activities with the potential to affect land and resource use are identified and mitigation developed to limit or avoid effects is presented. A pathways analysis is then used to focus further assessment on key interactions between the NSDF Project and the environment by evaluating the different effect pathways to determine if, after incorporation of mitigation, there is still potential to cause residual effects. Where effects are adequately mitigated and are not forwarded for further analysis (i.e., secondary pathways, or where mitigation will remove the pathway altogether), the reasons for concluding the assessment at this stage are articulated.

- **Step 4 - Identifying monitoring and follow-up** required to confirm effects predictions and address uncertainty (refer to Section 5.9.6 Monitoring and Follow-up).
- **Step 5 - Present a consolidated summary of conclusions and outcomes of the assessment** of residual effects on land and resource use (refer to Section 5.9.7 Conclusions).

It is important to note that the following environmental assessment steps outlined in Section 5.1 were not required as there were no primary pathways identified in the land and resource use assessment:

- present the methods and results of the residual effects analysis;
- describe the level of certainty and management of uncertainty; and
- classify and determine the significance of the predicted residual effects.

Information and areas of interest raised by the public, communities of interest, regulators, and First Nation and Métis communities during engagement that influenced the scope of the land and resource use assessment are summarized in Table 5.9.1-1. Other general areas of interests and questions raised during the engagement that pertain to the land and resource use assessment (if any) are documented in Appendix 4.0-15 Formal Public Feedback.

Table 5.9.1-1: Summary of Area of Interest Raised during Engagement Activities that Influenced the Scope of the Land and Resource Use Assessment

Area of Interest	How the Area of Interest Was Included in the Assessment
Interest was expressed over effects to fish from potential for contamination in the Ottawa River from the NSDF Project.	The spatial boundaries of the assessment were selected to include consideration of potential effects to the Ottawa River. CNL has been monitoring the environment extensively, specifically Perch Creek. The NSDF Project has used recent modelling to understand the potential for effects within the Perch Creek basin.
Interest over the destruction of terrestrial habitat.	An evaluation of the change in habitat availability and habitat distribution from the NSDF Project footprint is completed for each of the wildlife species selected as VCs.
Interest in cultural history of the NSDF Project site.	An archaeological assessment, including field surveys was completed for the NSDF Project site and surrounding area. Findings of this assessment were used to inform the NSDF Project design team, and subsequently, the NSDF Project footprint was modified so that archaeological sites identified during the field surveys would not be affected.
Interest in the continued use of the region for traditional purposes.	As the proposed undertaking occurs within the general area of the Algonquins of Ontario Settlement Boundary it is assumed that Algonquin of Ontario citizens continue to practice traditional land use activities throughout this region. As such, the assessment evaluated potential effects on traditional land and resource use.

The above information was used to frame the scope of the assessment and identify the VCs identified in Section 5.9.2. This assessment considers changes in wildlife harvesting and angling, outdoor tourism and recreation opportunities and other resource uses identified during the collection of baseline information at the local and regional scales. CNL has and will continue to meet with interested stakeholders and First Nations and Métis communities to receive input on the Project. The objectives of these meetings are to understand the priorities and interests of recreational and traditional users and to review potential mitigation measures to reduce or eliminate the effects of the Project.

5.9.2 Valued Components

Valued components refer to environmental features that may be affected by a project and that have been identified to be of concern by the proponent, scientists, government agencies, First Nation and Métis communities, or the public (The Agency 2014). Land and resource use VCs were selected based on the potential for the NSDF Project to interact with the features of the land and resource use environment. In addition, VCs for traditional land and resource use were selected based on consideration of a number of factors, including the following:

- knowledge of traditional land and resource use practices that interact with the environment;
- Aboriginal and/or treaty rights;
- engagement; and
- consideration of other environmental assessments.

The VCs selected for assessing potential effects on land and resource use conditions are presented in Table 5.9.2-1.

Table 5.9.2-1: Valued Components for the Land and Resource Use Assessment

Valued Component	Rationale for Selection
Land and Resource Tenures and Other Registered Interests	■ Project construction and operation must demonstrate compatibility with existing land use direction as expressed by responsible authorities based on a qualitative comparison of the Project with established land and resource designations in plans, policies and bylaws. ■ The Project has the potential to affect access routes/ access to commercial land and resource use areas (e.g., for existing mining, forestry, and agriculture). ■ The Project has the potential to affect the availability of commercial land and resource use opportunities.
Outdoor Tourism and Recreation	■ The Project has the potential to affect the access to outdoor tourism and recreational land and resource use opportunities associated with parks and protected areas, fishing, hunting, trapping and non-consumptive tourism and recreation. ■ The Project has the potential to affect the quality and quantity of outdoor tourism and recreation land use opportunities.
Archaeological Sites	■ Archaeological sites are an important aspect of First Nation and Métis communities cultural heritage. Archaeological sites are the focus of the archaeology discipline as archaeological sites are identified and protected by the *Ontario Heritage Act*.
Traditional Land and Resource Use by First Nation and Métis Communities	■ Trapping, hunting, fishing, and gathering were traditional and modern day land and resource use activities practiced by First Nation and Métis communities in the Ottawa Valley. These activities provide important links to cultural continuity and traditional way of life. ■ First Nation and Métis communities place a high degree of value on specific sites of cultural, historical, spiritual, social or ecological significance. These sites may have broader cultural significance related to the practice of formal or informal ceremonies at or near these sites.

To provide a focused assessment, the above noted VCs are further sub-divided into categories that are assessed in detail as part of the land and resource use assessment (Table 5.9.3-1). Assessment endpoints are qualitative expressions used to assess the significance of residual effects on VCs and represent the key properties of the VC that should be protected for future generations. The assessment endpoint for the land and resource use VCs are presented in Table 5.9.2-2. Measurement indicators represent properties of the environment and VCs that, when changed, could result in or contribute to an effect on a VC. Measurement indicators can be used to monitor the success of mitigation and management programs. The assessment endpoints and measurement indicators associated with the land and resource use assessment are outlined in Table 5.9.2-2.

Table 5.9.2-2 Assessment Endpoints and Measurement Indicators for the Land and Resource Use Assessment

Valued Component	Sub-component	Assessment Endpoints	Measurement Indicators
Land and Resource Tenures and Other Registered Interests	Land use designations	Maintenance of compatibility with provincial, regional and municipal land use designations	Compatibility of the Project with existing land use designations.
	Mining and aggregates	Continued land and resource use opportunities	■ Changes in access to land use areas and access routes used for land and resource tenures and other registered interests. ■ Changes in the availability of tenured land use opportunities and other registered interests.
	Forestry		
	Agriculture		
Outdoor Tourism and Recreation	Parks and protected areas	Continued land and resource use opportunities	■ Changes in access to outdoor tourism and recreation activities. ■ Changes in quality and quantity of outdoor tourism and recreation opportunities.
	Fishing		
	Hunting		
	Trapping		
	Non-consumptive tourism and recreation		
Archaeological Sites	N/A	Management of cultural and archaeological sites	Number, type and locations of archaeological materials or features that would contribute to an archaeological site and ability to recover archaeological materials or protect archaeological features.

Table 5.9.2-2 Assessment Endpoints and Measurement Indicators for the Land and Resource Use Assessment

Valued Component	Sub-component	Assessment Endpoints	Measurement Indicators
Traditional Land and Resource Use by First Nation and Métis Communities	Trapping	Continued traditional land and resource use opportunities	■ Changes in access to lands for trapping opportunities. ■ Changes in quality and quantity of trapping opportunities.
	Hunting	Continued traditional land and resource use opportunities	■ Changes in access to lands for hunting opportunities. ■ Changes in quality and quantity of hunting opportunities.
	Fishing	Continued traditional land and resource use opportunities	■ Changes in access to lands for fishing opportunities. ■ Changes in quality and quantity of fishing opportunities.
	Gathering	Continued traditional land and resource use opportunities	■ Changes in access to lands for gathering opportunities. ■ Changes in quality and quantity of gathering opportunities.
	Cultural Resources and Ceremonies	Continued access to cultural resources for ceremonial purposes	■ Changes in access to lands for cultural ceremonial purposes. ■ Changes in quality and quantity of ceremonial opportunities.

N/A = not applicable

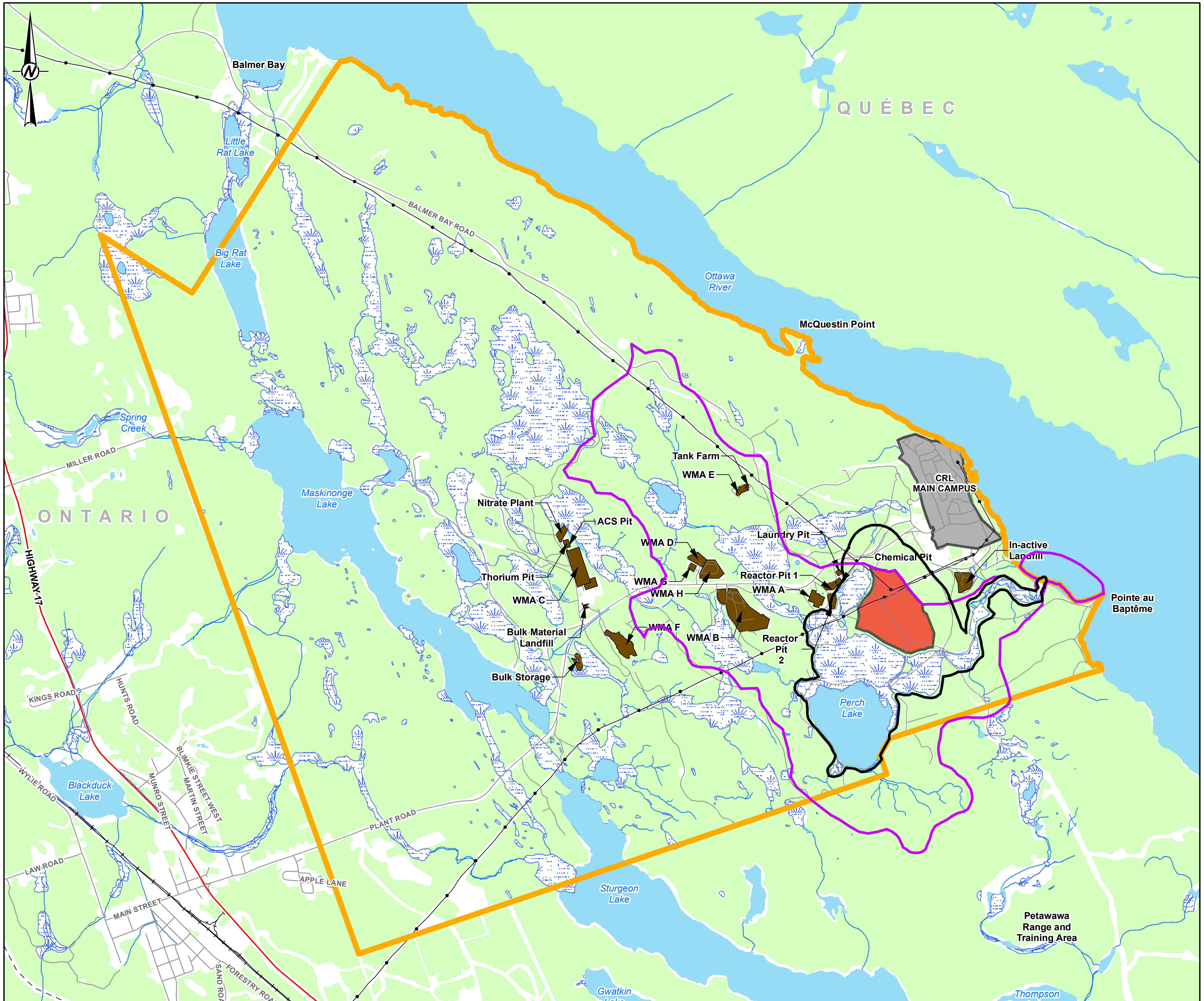
5.9.3 Assessment Boundaries

5.9.3.1 Spatial Boundaries

The spatial boundaries selected for the land and resource use assessment were chosen because they permit description of existing conditions in sufficient detail to enable potential project-VC interactions and effects to be identified, understood, and assessed, including understanding and assessing the contribution of the NSDF Project to cumulative effects. The spatial boundaries selected for the land and resource use assessment are presented on Figure 5.9.3-1 and are described below.

- **Site Study Area (SSA):** The SSA is defined as the NSDF Project footprint (i.e., where Project activities would be undertaken including the NSDF Project's proposed facilities, buildings and infrastructure). The SSA covers an area of approximately 34 hectares (ha; Figure 5.9.3-1).
- **Local Study Area (LSA):** The LSA is defined as the area within which there is potential for measurable effects to land and resource use VCs resulting from the proposed NSDF Project activities. The land use and resource use LSA corresponds with the combined area of the terrestrial and aquatics LSA used for the assessment of soils, vegetation and wildlife and covers approximately 222 ha (Figure 5.9.3-1). The LSA is defined to capture direct and indirect effects on the terrestrial and aquatic environment resulting from the Project (e.g., habitat loss, sensory disturbance for wildlife and changes to habitat from dust deposition) as these effects have the potential to result in subsequent effects on land and resource use.

- **Regional Study Area (RSA):** The RSA is defined as the area within which the potential effects of the NSDF Project may interact with the effects of other existing or reasonably foreseeable projects. The land use and resource use RSA corresponds with the combined area of the terrestrial and aquatics RSA used for the assessment of fish and fish habitat, vegetation and wildlife (Figure 5.9.3-1). As described in the air quality assessment (Section 5.2.1), the results at the LSA boundary (i.e., Chalk River laboratories (CRL) property boundary) are presented as this represents the highest ground-level concentrations of contaminants expected outside the CRL property. As such, the RSA is defined to capture direct and indirect effects on the atmospheric, terrestrial and aquatic environment resulting from the Project (e.g., habitat loss, sensory disturbance for wildlife and changes to habitat from surface water quality) as these effects have the potential to result in subsequent effects on land and resource use.



LEGEND

- HIGHWAY
- ROAD
- RAILWAY
- TRANSMISSION LINE
- NATURAL GAS PIPELINE
- RIVER/STREAM
- WATERBODY
- WETLAND
- SITE STUDY AREA (NSDF PROJECT SITE)
- CRL MAIN CAMPUS
- WASTE MANAGEMENT AREA (WMA)[1]
- CRL PROPERTY
- LOCAL STUDY AREA
- REGIONAL STUDY AREA

1 0 1

1:35,000 KILOMETERS

NOTE(S)

1. LIQUID DISPOSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.

REFERENCE(S)

1. BASEDATA ONTARIO MNRF 2016, CANVEC 2016, AND CNL 2016
2. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
3. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE18N

CLIENT

CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT

NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE

SPATIAL BOUNDARIES SELECTED FOR THE LAND AND RESOURCE USE ASSESSMENT

CONSULTANT

Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	SV
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.9.3-1

This page left intentionally blank

5.9.3.2 Temporal Boundaries

Temporal boundaries (i.e., project phases) establish the timeframe during which NSDF Project effects are assessed. The temporal boundary represents the timeframe during which project activities are actively occurring, and considers the duration of predicted residual effects. The duration of an effect is defined as the amount of time between the start and end of a Project activity or stressor (which is related to the project phases) plus the time required for the residual effect to be reversed. In some cases, a residual effect may be irreversible within the temporal boundaries of the Project or if the effects were predicted to last so far into the future that they could not be predicted with any level of certainty (e.g., residual effect lasts for thousands of years). The following phases were identified for the NSDF Project.

- **Construction Phase**: includes site preparation and all activities associated with the construction of the NSDF. This phase includes activities such as installing the necessary supporting and/or ancillary facilities and NSDF infrastructure to facilitate NSDF operations, inactive commissioning and systems testing, and transportation of construction materials. Construction activities are expected take place from 2018 to 2020.
- **Operations Phase**: includes all activities associated with the landfilling of waste receipt, waste placement, water management, wastewater treatment plant operations, vehicle movements into and from the NSDF Project site, and maintenance activities. The operations phase is expected to last approximately 50 years (i.e., 2020 to 2070).
- **Closure Phase:** includes activities necessary to complete the installation of the final cover and implementation of long-term monitoring. Closure activities are expected to start in 2070 and continue through to 2100, after which the NSDF Project will transfer into the post-closure phase.
- **Post-closure Phase:** has two discrete periods: Institutional Control and post-Institutional Control. The Institutional Control period includes implementation of both active and passive control throughout 2100 to 2400 (i.e., 300 years). During Institutional Control, groundwater monitoring and groundwater quality management will continue to demonstrate compliance with the safety case assumptions. Post-institutional Control occurs after year 2400 and continues indefinitely.

The temporal boundaries for the land and resource use assessment include consideration of effects of the NSDF Project from construction through to the end of post-closure.

5.9.3.3 Assessment Cases

This section will provide a brief description of the assessment cases considered in the land and resource use assessment, including the Base Case, Application Case and the Reasonably Foreseeable Development (RFD) Case.

- **Base Case –** This scenario represents existing conditions and characterizes effects from previous and existing developments and activities. The Base Case reflects the effects of existing infrastructure and services in the area, such as forestry, transportation, agricultural, mining, and residential and recreational development. Current effects from the existing CRL facilities and operations are considered part of the Base Case.

- **Application Case –** This scenario represents the effects of the Base Case combined with the predicted effects from the NSDF Project. The Application Case considers effects from the NSDF Project during construction through to post-closure.
- **The RFD Case –** This scenario represents the effects of residual adverse effects of the Application case combined with other reasonably foreseeable projects in the land and resource use RSA. There are no RFDs expected in the CRL property (i.e., the RSA) with the exception of new/upgrades to research and development facilities, new support infrastructure, and ongoing decommissioning and environmental restoration activities. New support infrastructure and research and development facilities will be located within existing disturbed areas on the CRL property (i.e., no disturbance to Greenfield areas). As such, potential effects from these activities are not expected to spatially overlap with potential effects to land and resource use from the NSDF Project. The end-state plan for the CRL site will be to return lands disturbed by site activities to a condition that is physically stable, and safe in keeping with the land use and landscape of the day. Therefore, decommissioning and environmental restoration activities are anticipated to positively affect land and resource use. Because RFDs will either have no spatial overlap or are likely to positively affect land and resource use, an RFD Case is not presented as part of this assessment.

5.9.4 Description of the Environment

This section describes the setting and characterization for land and resource use, including land and resource tenures, outdoor recreation and tourism, archaeological sites, and traditional land and resource use by First Nation and Métis communities, as relevant for the assessment of the NSDF Project. It describes the existing conditions (i.e., Base Case) against which potential changes from the NSDF Project are compared and evaluated.

5.9.4.1 Land and Resource Tenures and Outdoor Recreation and Tourism

5.9.4.1.1 Methods

Baseline information was collected from a range of information sources and analyzed to submit a profile for the land and resource use conditions in the LSA and RSA, and surrounding areas. Baseline information was collected from the following sources:

- provincial, regional and local land use Official Plans and Zoning By-laws, as applicable;
- the Ministry of Natural Resources and Forestry's (MNRF) Land Information Ontario (LIO) spatial land use database (MNRF 2016a);
- Natural Resources Canada's (NRCan's) CANVEC spatial land use database;
- municipal and regionally-based outdoor tourism, recreation and economic development webpages and reports;
- information on parks and protected areas available through Ontario Parks and Parks Canada; and,
- publicly available wildlife harvesting data available through the MNRF.

5.9.4.1.2 Land and Resource Tenures and Other Registered Interests Results

5.9.4.1.2.1 Land Use Designations

The NSDF Project is located entirely within the CRL property (i.e., RSA), which is located on federal lands. Therefore, aside from the operations and activities undertaken by CNL, other land uses of the CRL property are prohibited due to restricted public access. The CRL property is located in Renfrew County, Ontario on the shore of the Ottawa River. The property has a total area of 4,000 ha approximately 200 kilometres (km) northwest of Ottawa and is within the boundaries of the Corporation of the Town of Deep River. The Federal Department of National Defence Garrison Petawawa borders the CRL property to the southeast, and the Village of Chalk River in the Municipality of Laurentian Hills is to the southwest. The Ottawa River forms the northeastern boundary of the property.

County of Renfrew Official Plan

The NSDF Project is located within the County of Renfrew, however, it is not subject to provisions under the County of Renfrew Official Plan (OP). Adopted by Council in 2002 and approved by Ministry of Municipal Affairs and Housing in 2003, the OP sought to consolidate the rural and small town policies and plans, but still provided each municipality with the opportunity to produce their own OP if desired (County of Renfrew 2003). The current OP subsequently applies to ten municipalities, but does not include the Town of Laurentian Hills, where the Project is situated. Under Schedule A (Map 1 of 2) of the County of Renfrew OP, the SSA is identified as “Non County Areas” and subsequently, the County OP does not apply to the NSDF Project. There are no associated restrictions in the OP related to current land use or land use designations or compatibility of the NSDF Project with the OP.

Town of Laurentian Hills Official Plan

The NSDF Project falls within the Township of Laurentian Hills. As noted above, the Town of Laurentian Hills (the Town) is a restructured municipality that consolidated the Township of Rolph, Buchanan, Wylie and McKay, as well as the Village of Chalk River as of January 1, 2000 (Town of Laurentian Hills 2010). The Town’s current OP was adopted on September 22, 2010 following the completion of a five year review. The lands overlapped by the SSA are currently identified as “Restricted Access Crown Land” within the Town’s OP (Schedule A). The presence of Crown Land is not uncommon in the Town of Laurentian Hills; as identified in Section 2.6 of the Town’s OP, a significant proportion of the Town’s land base (51.8%) is made up of Crown Land or federal land, which are not subject to municipal land use controls. In accordance with Section 5.12 of the Town’s OP:

> “The Municipality recognizes that there are no provisions in the *Planning Act* which binds the Federal Crown in the administration and use of its lands. Section 6 (2) of the *Planning Act* requires the Ministries and agencies of the Ontario government, including Ontario Power Generation Inc. and Ontario One Networks as set out in Sections 3, 6, 48 and 62 of the *Planning Act*, shall have regard to the Municipality’s planning policies and consult with the Municipality before carrying out or authorizing any undertaking considered to affect the Municipality. Council’s intent is to ensure that the planning process be applied to changes of use, for example, that may arise from the sale or disposition of Crown Lands to the private sector”.
>
> (Town of Laurentian Hills 2010).

The Town of Laurentian Hills Zoning By-law came into force on June 20, 2012. The SSA is identified as Crown Lands on the associated Index Map and accordingly, the provisions of the By-law do not apply (Sections 1.3 and 4.7; Town of Laurentian Hills 2012).

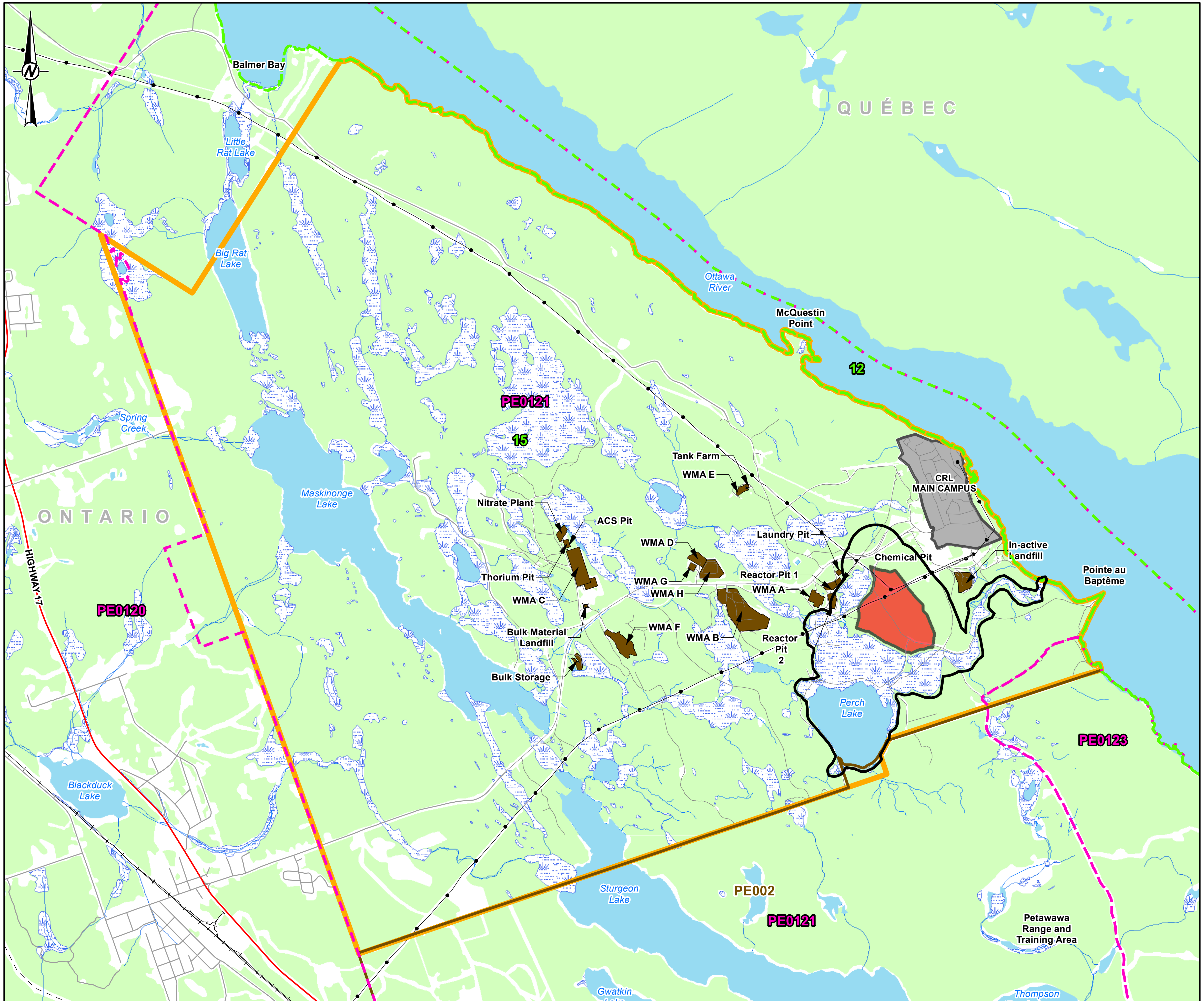
Natural Heritage Features and Areas

In accordance with Section 6.4 of the Town's OP, "Natural heritage features and areas are those areas which are important for their environmental and social values as a legacy of the natural landscapes of the area. Collectively, the individual natural heritage features and areas within a given Planning Area form a natural heritage system. It is intended that the particular features identified in the Town of Laurentian Hills will be conserved for their natural heritage value". Section 6.4 (3) states that "Council is committed to protecting and managing identified wetlands as ecosystems which are important as habitat, for water quality, flood control and water storage and recharge areas, as well as for their value for passive recreation (Town of Laurentian Hills 2010). The NSDF Project is not subject to provisions under the OP.

5.9.4.1.2.2 Mining and Aggregates

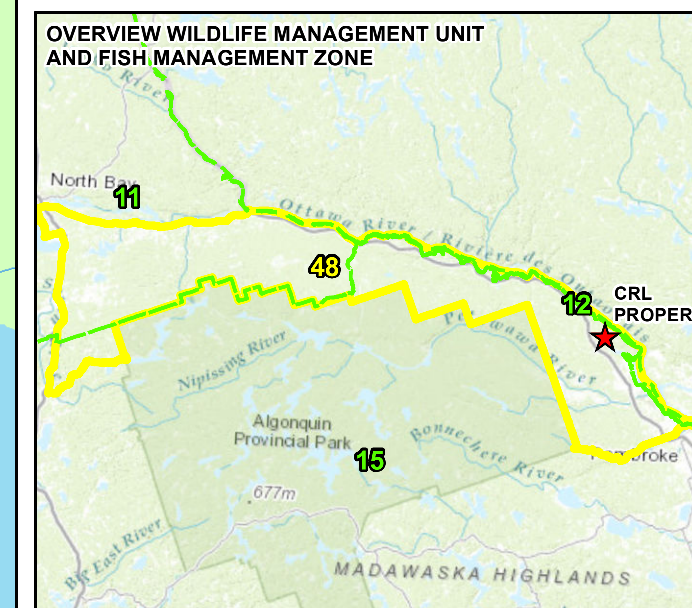
Aggregate resources are regulated under Ontario's *Aggregate Resources Act* on Crown Lands and most private lands (MNRF 2012). The MNRF manages aggregate resources in collaboration with the Ministry of Northern Development and Mines (MNDM) and the Ontario Aggregate Resources Corporation. The RSA is located within one Aggregate Designated Area, which prohibits the extraction of aggregates on these private lands without a license. Through Authorized Aggregate Sites, aggregate site clients are provided permits and/or licences to extract resources from one or more sites. However, there are no active Authorized Aggregate Sites (i.e., licenced and permitted pits and quarries) in the land and resource use RSA. Aggregate Designated Area boundaries are presented on Figure 5.9.4-1 (MNRF 2016a). There are no existing mine sites, active mining claims, pending mine claims, active dispositions or active withdraws in the RSA (MNRF 2016a).

232 509220 REPT 004
UNRESTRICTED



LEGEND

- HIGHWAY
- ROAD
- RAILWAY
- TRANSMISSION LINE
- NATURAL GAS PIPELINE
- RIVER/STREAM
- WATERBODY
- WETLAND
- SITE STUDY AREA (NSDF PROJECT SITE)
- CRL MAIN CAMPUS
- WASTE MANAGEMENT AREA (WMA)[1]
- REGIONAL STUDY AREA (CRL PROPERTY)
- LOCAL STUDY AREA
- BAIT HARVEST AREA
- FISH MANAGEMENT ZONE
- TRAPLINE AREA
- WILDLIFE MANAGEMENT UNIT



1 0 1
1:35,000 KILOMETERS

NOTE(S)
1. LIQUID DISPOSAL AREA ENCOMPASSES REACTOR PIT 1 AND 2, CHEMICAL PIT AND LAUNDRY PIT.

REFERENCE(S)
1. BASEDATA ONTARIO MNRF 2016, CANVEC 2016, AND CNL 2016
2. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
3. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE18N

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
HUNTING, FISHING AND TRAPPING IN THE LAND AND RESOURCE USE LOCAL AND REGIONAL STUDY AREAS

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	SV
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.9.4-1

This page left intentionally blank

5.9.4.1.2.3 Forestry

The MNRF is responsible for the long-term health of Crown forests. Where active forestry is desired, the MNRF shares this responsibility with forest product companies through forest management planning guided by the *Crown Forest Sustainability Act, 1994* and the Ontario *Environmental Assessment Act*. Approximately 44% of Ontario's Crown forests are managed forests, divided into forest management units (FMUs; MNRF 2016b).

These FMUs are managed by various First Nation and Métis and non-First Nation and Métis companies through forest management plans (FMPs). The MNRF requires FMPs to be developed prior to any forestry activity within these FMUs. The FMPs determine where and how much harvesting can occur, where roads can be built and how much forest will be renewed. These plans are prepared by registered professional foresters with input from local citizens, First Nation and Métis communities, stakeholders and the public, to ensure sustainability while finding a balance of economic, social and environmental values (MNRF 2016b). The FMPs are approved for 10-year terms.

The RSA is located within the Ottawa Valley Forest FMU, licensed to and managed by Ottawa Valley Forest Inc. (MNRF 2016a). However, because the RSA is located on federal lands, there are no agreement forest areas, wood use areas, or forest processing facilities in the RSA (MNRF 2016a).

In the western region of the SSA, approximately 2.6 ha of land is occupied by a Petawawa research forest plantation. The plantation was established in 1956 to determine frost and White Pine weevil resistance in Norway Spruce trees. The plantation was abandoned in the 1980's, and personnel with the Petawawa Research Forest have confirmed this plantation is no longer required for research purposes.

5.9.4.1.2.4 Agriculture

The NSDF Project is located in a more northern region of Ontario, which has a less prominent history of agriculture than more southern parts of the province. Consequently, the spatial provincial Agricultural Resource Inventory, which identifies and characterizes agricultural resources in the Province of Ontario, does not extend into the RSA (Ministry of Agriculture, Food and Rural Affairs 2016). The RSA is restricted to the CRL property, and land uses of the CRL property are prohibited due to restricted public access.

5.9.4.1.3 Outdoor Tourism and Recreation Results

5.9.4.1.3.1 Parks and Protected Areas

There are no municipal parks, provincial parks, national parks, conservation reserves, non-governmental organizations (NGO) Nature Reserves, Natural Heritage System Areas, Significant Ecological Areas, Heritage River Systems or Areas of Natural and Scientific Interest (ANSIs) identified within the RSA (MNRF 2016a). No Ontario Conservation Authorities maintain jurisdiction over the RSA, nor are there any conservation areas within a 50 km radius of the NSDF Project (Conservation Ontario 2015).

5.9.4.1.3.2 Fishing

In the Province of Ontario, fishing is managed through fisheries management zones (FMZs), used by the MNRF to establish zone-specific limits and seasons that protect vulnerable fisheries, re-establish fish populations, adjust fishing seasons for different climates, and allow more fishing in thriving fishery zones (MNRF 2016c). These are administered under the *Fish and Wildlife Conservation Act*, 1997. The RSA and LSA fall within FMZs 12 and 15, while the SSA only transects FMZ 15.

FMZ 12 (Ottawa River) is located along the Ontario/Quebec border. It is a large and diverse fishery on the Ottawa River, valuable for the recreational and tourism-based fishing industries. It represents an important Eastern Ontario fishery for Walleye (*Sander vitreus*), Sauger (*Sander canadensis*), Northern Pike (*Esox Lucius*), Muskellunge (*Esox masquinongy*), Largemouth Bass (*Micropterus salmoides*), and Smallmouth Bass (*Micropterus dolomieu*; MNRF 2016d).

FMZ 15 (Parry Sound, Bancroft, Pembroke, Algonquin Park) is located in central Ontario. This large zone has numerous natural lake and brook trout lakes, a well-developed road network and moderate angling effort, includes fishing opportunities in Algonquin Provincial Park, and represents an important recreational fishery for Lake Trout (*Salvelinus namaycush*), Brook Trout (*Salvelinus fontinalis*), Walleye, Northern Pike, and Smallmouth Bass. The FMZ is stocked with Lake Trout and Brook Trout to increase angling opportunities (MNRF 2016e).

As with other harvesting activities, the MNRF regulates fishing by establishing permitted seasons and limits in each FMZ. For some species, fishing seasons are open all year, whereas others face more restrictions. These fishing seasons influence levels of fishing activity in the SSA, LSA, and RSA as presented in Table 5.9.4-1.

Table 5.9.4-1: Fishing Seasons by Fisheries Management Zone (2016)

Fish Species	Open Fishing Season	
	FMZ 12	FMZ 15
Walleye and Sauger	January 1 to March 31 & Friday before 3rd Saturday in May to December 31	January 1 to March 15 & 3rd Saturday in May to December 31
Largemouth & Smallmouth Bass	Friday before 4th Saturday in June to November 30	4th Saturday in June to November 30
Northern Pike	January 1 to March 31 & Friday before 3rd Saturday in May to December 31	January 1 to March 31 & 3rd Saturday in May to December 31
Muskellunge	Friday before 3rd Saturday in June to December 15	1st Saturday in June to December 15
Yellow Perch	Open all year	Open all year
Crappie	Open all year	Open all year
Sunfish	Open all year	Open all year
Brook Trout	Friday before 4th Saturday in April to September 30	January 1 to September 30
Brown Trout* & Rainbow Trout	Friday before 4th Saturday in April to September 30	Open all year
Lake Trout	Friday before 4th Saturday in April to September 30	January 1 to September 30
Splake	Friday before 4th Saturday in April to September 30	Open all year
Atlantic Salmon	September 30 S - 2 C - 1 Atlantic Salmon* Friday before 4th Saturday in April to September 30	Closed all year
Lake Whitefish	Open all year	Open all year
Lake Sturgeon	Closed all year	Open all year
Channel Catfish	Open all year	Open all year
Pacific Salmon	—	Open all year

Source: MNRF 2016f.

— = No information provided by the MNRF.

The use of live organisms as bait remains common among anglers, and bait types vary depending on the species of fish being sought (Kerr 2012). Surveys suggest that almost 80% of Ontario anglers use live bait (e.g., worms, baitfish, frogs and/or crayfish) (Kerr 2012). Ontario anglers can choose to harvest or purchase bait (Kerr 2012). Commercial bait harvesting on Ontario is licenced through Bait Harvesting Areas (BHA). Bait harvesters pay approximately $300 per year for the exclusive rights to each BHA. The land and resource use RSA overlaps three BHAs, PE0121, PE0123 and PE0120, which cover 3,956.1 ha collectively (MNRF 2016a). There are no fishing access points identified by the MNRF in the RSA (MNRF 2016a).

5.9.4.1.3.3 Hunting

The MNRF manages hunting activities in Ontario through 95 regulated wildlife management units (WMUs). Each WMU has customized restrictions for the types of game that can be hunted, open season dates, and hunting methods permitted (MNRF 2015).The RSA is located within WMU 48, which extends from North Bay to Pembroke along the Ottawa River.

To effectively balance wildlife populations with the demands of harvesting activities, the MNRF establishes seasonal dates where hunting by local residents and non-residents is permitted in the WMU. Hunting seasons are adjusted every year as necessary. The presentation of baseline conditions focuses on moose, white-tailed deer and black bear, three indicator species considered important to recreational hunting in Central and Eastern Ontario. Moose, deer and bear hunting seasons in WMU 48 for residents and non-residents are presented in Table 5.9.4-2.

Table 5.9.4-2: Firearm Hunting Seasons for Resident Hunters in Wildlife Management Unit 48 (2016)

Species	WMU 48	
	Resident Hunters	Non-Resident Hunters
Moose	Adult & Calf Moose Oct. 3 to Oct. 8	No Season
Deer	Nov. 7 to Nov. 20	Nov. 7 to Nov. 20
Black Bear	May 1 to Jun. 15	May 1 to Jun. 15

Source: MNRF 2016g.

The MNRF also monitors harvest data to establish sustainable hunting seasons year over year and to assess levels of hunting activity in each WMU. Publicly available harvest data for moose in the RSA is presented in Table 5.9.4-3. In 2013; approximately 948 hunters were active in WMU 48, harvesting a total of 54 moose.

Table 5.9.4-3: Resident Moose Hunter and Harvest Data for Wildlife Management Unit 48 (2008-2013)

WMU	Year	Estimated Active Resident Moose Hunters	Estimated Total Moose Harvest by Resident Hunters
48	2008	803	26
	2009	1,007	44
	2010	1,059	75
	2011	1,182	54
	2012	1,092	60
	2013	948	54

Source: MNRF 2014a.

The number of resident white-tailed deer hunters active in WMU 48 varied between 2008 and 2013, with 2,862 licensed hunters active in 2013. The number of deer harvested rose at a higher rate over the same time period, from 767 to 948 between 2008 and 2013 (an increase of 23.6% overall; MRNF 2014b). Resident hunter and harvest figures for these years are presented in Table 5.9.4-4.

Table 5.9.4-4: Resident Deer Hunter and Harvest Data in Wildlife Management Unit 48 (2008-2013)

WMU	Year	Estimated Active Resident Deer Hunters	Estimated Total Deer Harvest by Resident Hunters
48	2008	2,621	767
	2009	2,698	716
	2010	2,010	639
	2011	2,994	775
	2012	3,026	805
	2013	2,862	948

Source: MNRF 2014b.

The number of bear hunters also fluctuated in WMU 48 between 2008 and 2013, with a high of 547 bear hunters in 2009 and an estimated 365 bear hunters by 2013. Harvest levels fluctuated accordingly, with the largest harvests occurring in 2009 (i.e., 176 bear harvested) and the lowest harvests experienced in 2013 (i.e., 37 bear harvested). The number of resident and non-resident bear hunters and their harvests between 2008 and 2013 are presented in Table 5.9.4-5. There are no Bear Management Areas (BMAs)[1], or Crown Game Preserves overlapping the RSA.

Table 5.9.4-5: Resident and Non-Resident Bear Hunters and Harvests in Wildlife Management Unit 48 (2008 to 2013)

WMU	Year	Resident and Non-Resident Bear Hunters	Bear Harvest
48	2008	334	62
	2009	547	176
	2010	507	129
	2011	458	78
	2011	464	55
	2013	365	37

Source: MNRF 2014c.

[1] Bear Management Area is an area of Crown land licenced annually to a tourist operator for providing bear hunting services to non-resident clients. Some BMAs can completely surround private or patent land. Bear hunting services can occur on these lands provided the licenced tourist operator allocated the BMA has obtained permission of the land owner to provide bear hunting services on the property.

5.9.4.1.3.4 *Trapping*

In the Province of Ontario, trapping is regulated under the *Fish and Wildlife Conservation Act,* administered by the MNRF (MNRF 2016h). Individuals must hold a trapping licence to harvest fur, identifying where each individual can trap, in order to monitor furbearer populations and regulate trapping activities through seasons and harvest quotas (MNRF 2016h). Access to the trapline tenures in the region is gained by obtaining a license from the MNRF, which can be secured by: proving Canadian citizenship; holding a valid hunting/fishing Outdoors Card, and successfully completing the MNRF's Fur Harvest, Fur Management and Conservation Course (MNRF 2016h). There are two traplines near the CNL property PE025 and PE002; however, the RSA is restricted to the CNL property, and land uses of the CRL property are prohibited due to restricted public access.

5.9.4.1.3.5 *Non-consumptive Tourism and Recreation*

While tourism and recreation opportunities exist in Renfrew County, there are no tourism and recreation features in the RSA. There are also no access points, boat caches (private or commercial), boathouses, club houses, designated camping sites, recreation camps[2], tourism establishment areas[3], potential tourism establishment areas, beaches, picnic sites, golf courses, resting areas, trailheads or Ontario Trail Network (OTN) trails in the RSA (MNRF 2016a). A known site of significance on the CRL property is what is known as the Pointe au Baptême Site. Recreational boaters on the Ottawa River frequently use Pointe au Baptême as a picnic stop, however the white chain fence (signifying the location of the suspected burials) is not easily identifiable from the beach.

5.9.4.2 Archaeological Environment

5.10.1.1.1 Archaeological Context

The NSDF Project occurs within the general area of the Algonquins of Ontario Settlement Boundary. A literature review and a review of the oral history of the Algonquin people were completed to detail the Algonquin history from the proto-historic to the attempted establishment of a reserve in the early 20th century. This review provided important historical context that increased the likelihood of identifying archaeological sites and provides context for the archaeological sites identified. The full historical review is presented in the preliminary archaeological assessment for the NSDF Project (Swayze and Cameron 2016). To summarize briefly, this historical review identified factors that must have affected technological and settlement pattern change for the Algonquin people that, theoretically, should be reflected in the archaeological record. These include:

- technological change from "quartz time" to the "iron age" and the resultant change in cold season settlement patterns from fish, stored nuts and wild rice to fur harvesting and reliance on cervid and beaver; and
- beginning in the mid-19th century there was a homesteading movement in the upper Madawaska Valley, which involved technological change and a more sedentary settlement pattern.

According to the Borden (1952) system of archaeological site registration, the CNL property is in the CaGi "Borden Block" (a rectangular area, about 13 km by 19 km) that straddles both sides of the Ottawa River. There are 14 archaeological sites recorded in the CaGi block, but only two sites were recorded within the CRL property.

---

[2] A Recreation Camp is a polygon feature that identifies an area used for commercial tourist operations with a focus on outdoor activities other than hunting and fishing (MNRF no date [a]).

[3] A Tourism Establishment Area is a polygon feature that identifies an area containing facilities and services for tourists (MRNF no date [a]).

In 1955, the National Research Universal (NRU) site was discovered in a sand deposit, approximately 3 metres (m) above the waterline, near the NRU reactor. The site was not registered with the Borden system and the disposition of the artifacts is uncertain; although they may be at the Canadian Museum of Civilization. Bone, pottery sherds and chert chips were found in an area approximately 15 m by 60 m. Most artifacts were disturbed, although one intact refuse pit was excavated. The pottery was determined to match Middle Woodland (Point Peninsula) activity from approximately 2,000 years ago.

In 2008, CNL developed an Archaeological Master Plan that resulted in a formal Cultural Resource Management (CRM) program at CNL. The CRM program includes an archaeological potential model which assists in locating areas of archaeological potential, and a robust cultural resource inventory of heritage sites. To date, the CRM program at CRL has identified over 50 heritage sites that are registered with the Ontario Ministry of Tourism Culture and Sport (OMTCS), within the CRL property. There are six archaeological sites previously recorded within 1 km of NSDF Project site, but none are located directly within the NSDF Project footprint. Each of these sites are described below.

CaGi-54 South Shore is a small early postglacial Pre-Contact Period site discovered on the edge of the D6 115 kilovolt (kV) hydro corridor at 181 to 183 metres above sea level (masl) (Swayze 2008). Stage 3 test excavations were carried out at CaGi-54 in 2010 to collect a larger artifact sample and to determine the nature and condition of the deposit. Ten one-metre units were excavated and a total of 135 stone tools were recovered. The raw material consists of quartz and metamorphic rock available in the till. No formal artifacts or exotic material occurred. The excavation of an additional 35 test pits determined that the deposit was isolated in the hydro corridor, but it continued for some extent to the north. In terms of cultural affiliation, CaGi-54 is consistent with the Gulf of Main Archaic Tradition (Robinson 1992) even though it probably dates to the Palaeo-Indian time period (Swayze and McGhee 2011).

CaGi-52 Communications Tower is an early postglacial Pre-Contact Period site that was recorded in 2008 during a Stage 2 assessment of the footprint for the communication tower (Swayze 2010). A collection of 52 stone artifacts, similar to the artifacts recovered from CaGi-54, was obtained from nine positive Stage 2 test pits, which were expanded into Stage 3 test units. Similar to the South Shore site, CaGi-52 is consistent with the Gulf of Maine Archaic Tradition, even though the 180 m strand it is associated with pre-dates the earliest maritime sites.

Pole 191 Stack Road was recorded during a Stage 2 assessment of wood pole replacements along the D6 115 kV hydro corridor and was assigned the temporary designation Borden Number CaGi-G (Swayze 2012). Eleven test pits were excavated around this pole structure and there were three positive results. Test units were excavated around each positive test pit but in total, only nine stone artifacts were discovered. The recovered stone artifacts are consistent with the Gulf of Maine Archaic Tradition.

CaGi-37 Blimkie Farm consisted of a two room, two storey log house with stone and cement foundations, three outbuildings and a laneway. Much of the site has been disturbed by road and fence construction in the area. Artifacts on the surface include mower and sleigh parts, ceramics, and glass.

CaGi-40 Parking Lot is an Early Archaic site under a new parking lot. It was found in 2007 with assistance of the Stewardship Rangers and the Earthwalkers of Pikwakanagan. The site was along the relic shoreline of the recessional Champlain Sea.

CaGi-53 Parking Lot was discovered in 2008. The site consists of expedient stone tools associated with an early postglacial low water event. The deposit was subsequently inundated and buried under riverine sediments, which have affected the condition of the artifacts.

The *Canadian Environmental Assessment Act, 2012* (CEAA 2012) requires a designated project to consider whether changes to the environment caused by project activities will adversely affect cultural heritage resources. Following the guidance provided in the *Reference Guide on Physical and Cultural Heritage Resources* (The Agency 1996), an archaeological assessment was completed for the NSDF Project (Swayze and Cameron 2016) in accordance with the *Standards and Guidelines for Consultant Archaeologists* (Ontario Ministry of Tourism and Culture [OMTC]). Archaeological assessments in Ontario are completed in accordance with the *Standards and Guidelines for Consultant Archaeologists* (OMTC 2011). These standards and guidelines identify four main stages for completing archaeology assessments. The purpose of the four stages is:

- discover any archaeological resources on the lands that are being developed;
- determine the degree of cultural heritage value of any archaeological resources found on the property;
- recommend the most appropriate strategies for conserving archaeological sites prior to land development activities; and
- implementing long-term protection strategies for archaeological sites to be affected by the project or if protection of the site is not a viable option, archaeological excavation may be completed to document the site and remove the artifacts before construction begins.

An archaeological assessment was completed for the NSDF Project (Swayze and Cameron 2016) in accordance with the *Standards and Guidelines for Consultant Archaeologists* (OMTC 2011). This assessment was submitted to the Minister of Tourism and Culture on March 2017 as a condition of licensing in accordance with the *Ontario Heritage Act, 1990*.

The following provides a summary of the archaeological assessment completed for the NSDF Project as document in *Cultural Resource Management At Canadian Nuclear Laboratories, 2016 Stage 1, 2 & 3 Archaeological Assessments At The Near Surface Disposal Facility (Nsdf) On Part Of Lots 20-23 Ranges A & B Buchanan Township (Geo.), Renfrew County* (Swayze and Cameron 2016).

5.10.1.1.2 Archaeological Assessment

5.10.1.1.2.1 Methods

Licenced by the Ontario Ministry of Tourism and Culture, the consultant archaeologist conducted the Archaeological Assessments in accordance with the *Standards and Guidelines for Consultant Archaeologists* (OMTC 2011). These standards and guidelines identify four main stages for completing archaeology assessments. The four stages are:

1) Background Study and Property Inspection
2) Property Assessment
3) Site-specific Assessment

4) Mitigation of development effects during the 2016 field season Stage 1 to 3 were completed. During the season, interim reports were provided for Stage 2 and Stage 3 work outlining the process, the identification of material and the subsequent recommendations

Canadian Nuclear Laboratories contracted Kinickinick Heritage Consulting and Cameron Heritage Consulting to complete the field work component of the Archaeology Assessment for the NSDF Project. The following sections are based on information provided in the Interim Reports prepared by Swayze and Cameron (2016). A complete Archaeological Assessment Report will be submitted to the OMTC by March 2017. All of the reports have been made available for review by First Nation and Métis communities and the Public.

Stage 1&2 Assessments

Under the Standards and Guidelines, the OMTC understands that much of northern Ontario and the Canadian Shield present obstacles to archaeological assessment including less detailed mapping and difficulties of access. The OMTC *Standards and Guidelines for Consultant Archaeologists* (OMTC 2011) makes allowance for assessments carried out in these areas where the bedrock is Pre-Cambrian Canadian Shield.

A desktop assessment (Stage 1 Background Study and Property Inspection) was completed to identify areas where potential archaeological resources may exist. The desktop assessment focused on the underlying principles of archaeological resource prediction, particularly of a hunter-gatherer society, including the proximity to water and the association of archaeological sites with certain landforms. The first assumes that human habitation is dependent upon potable water and that economic activity will occur most frequently on the shores of major bodies of water that offer biodiversity and biomass and act as communication and transportation corridors. The second assumes that the physical site and setting of human activity will not occur randomly on the terrain, but will reflect a choice of soil, drainage and landform that reflect economic decisions. A desktop review of historical geologic maps was completed to identify areas of archaeological potential, in particular, relic shorelines created over the millennia through glaciation.

Stage 2 (Property Assessment) begins with test pit surveys completed in areas where archaeological potential was identified during the background study and property inspection (Stage 1). Test pit surveys were completed over the entire property, digging at two intervals: every 5 m within 100 m of each major relic shore and every 10 m within 101 to 150 m above the former waterline.

Test pits were approximately 30 centimetres (cm) by 30 cm in size and were excavated by hand with a shovel and masonry trowel to a depth at least 5 cm into the parent material. Given the shallow nature of the soil, some test pits met this condition at 15 cm to 20 cm below surface; however, most test pits were excavated to 30 cm depth and frequently as deep as 40 cm. The back dirt was passed through a 6 millimetre (mm) mesh and the screen inspected carefully for artifacts or samples of potential artifacts.

The second phase of Stage 2 involved “infilling” where at each positive test pit, further excavation was completed to determine if further inspection of the area was necessary. The procedure consisted of excavating infill test units around the positive test pit, in a “compass rose” pattern, at 2.5 m distance, as well as the excavation of a 1 m × 1 m unit over the discovery spot. The infill excavation methods were identical to that described above for test pit survey. Artifact samples from infill test pits were tagged and bagged according to date, excavator, sequential number and infill unit location.

Stage 3 Assessment

The Stage 3 component of the Archaeology Assessment is a site-specific assessment and involves controlled surface pick up of material and text unit excavation determining the location and number of significant test pits. To accomplish this, test excavations were carried out wherever five or more artifacts of any kind were recorded during Stage 2, and within any area (i.e., a 10 m by 10 m area). The procedure consisted of establishing a permanent datum at each cluster of positive test pits and superimposing a 1 m grid over the area to be tested. Grid units were then excavated out at 5 m intervals over the prescribed area. An additional 20% of units were then placed at selected areas where artifact concentrations might be expected. These grid units were excavated by hand with a shovel and trowel to at least 5 cm depth into the parent material. The back dirt was passed through a 6 mm screen and the rock samples in it were carefully examined for archaeological material. In accordance with the OMTC *Standards and Guidelines for Consultant Archaeologists* (OMTC 2011), when dealing with Early Archaic archaeological sites, 20% of the back dirt from the grid units was passed through a 3 mm screen to determine if there were any tiny retouch flakes or beads, that could slip through the standards screen.

Stage 4 Assessment

Stage 4 in an Archaeological Assessment involves implementing long-term management strategies for those sites recommended for mitigation in Stage 3. Mitigation measures established for the management of significant artifacts identified in Stages 2 and 3 will be implemented in 2017.

5.10.1.1.2.2 Results and Recommendations

Stage 1 & 2 Assessments

The desktop review (Stage 1 Background Study and Property Inspection) determined that the majority of the NSDF Project footprint had some level of archaeological potential (Figure 4 of Swayze and Cameron 2016). In general, the areas of archaeological potential include:

- within a 150 m buffer above the elevation of a relic shoreline;
- within a 100 m buffers above a major water body, such as the shoreline of a lake or river;
- within a 50 m buffer around secondary areas of archaeological interest (like the shorelines of streams, wetlands, and intermittent creeks and landforms like lookouts, rock-faces, or sources of suitable rocks for tool manufacture); and
- within a 50 m buffer on each side of an historical road.

Large areas of high archaeological potential were identified due to proximity to a relic shoreline or the historical Mattawa Road. The relic shorelines are associated with the creation of the Champlain Sea and its regression over several millennia. Relic shorelines of the Champlain Sea within the NSDF Project footprint are located at 180, 170 and 159 masl, at which the elevation of the former sea level stayed for several centuries at a time. Areas of high archaeological potential were identified as 100 m above each relic shoreline. Areas of moderate potential were identified as above 101 to 150 m of each relic shoreline. Low potential terrain within the NSDF Project footprint consists of organic terrain that cannot be tested because of standing water or water saturated soil conditions.

Approximately 9,000 test pits have been excavated with only 337 of these identified as positive test pits (approximately 3.7%). The positive test pits above 180 masl were assigned the Borden Number CaGi-65; while

those between 170 and 179 were designated CaGi-66; and those between 159 and 169 are designated CaGi- 67 (Figure 5 of Swayze and Cameron 2016). In total, approximately 450 artifacts were discovered, usually only one or two artifacts per test pit.

As a result of infill excavations, 117 of the original 337 positive test were determined to be insignificant and are no longer of any heritage concern. However, 53 test pits are now “areas”” (10 x 10 m area) containing more than five artifacts of any kind and warrant test excavation on a grid. Most of these test pits were incorporated into existing test excavation areas, although a few are small 25 square metre (m^2) outliers. The infill excavation added approximately 400 artifacts to the collections.

Stage 3 Assessment

Analyses of the distribution of the original positive test pits, and the frequency of artifacts per test pit, indicated that at least 35 areas warranted further test excavations on a grid (Figure 7 of Swayze and Cameron 2016). Twenty-three of these areas are in CaGi-65, five are in CaGi-66, and seven are in CaGi-67. As a result of these archaeological assessment, modifications to the Project footprint were made to avoid a homestead. Upon completion of all the above text excavations, the consultant recommended two sites for Stage 4 Mitigation.

In conclusion the assessment process identified 337 positive test pits, areas of heritage concern, and, through infill excavation, determined that 35 areas require test excavation on a grid. These excavations are on-going but it is expected that, through elimination, the test excavations will identify some areas of significance, or heritage concern, where further Stage 4 deposit removal excavations will be necessary.

Stage 4 work to manage artifacts identified and confirmed in Stages 2 and 3 is expected to take place in 2017.

Site Analysis and Results

Indicators of an archaeological site’s significance and importance include: representativeness, site type or function, age, rarity, depositional integrity, preservation of organics, artifact and feature frequency and density, the presence or absence of human remains and burials, and deeply buried archaeological material (OMTCS 2011). The cultural heritage and scientific value, as well as the potential value to a community or as a public resource are also considered (OMTC 2011). These criteria are discussed below in terms of how they apply, generally and specifically, to the NSDF Project archaeological material (Swayze and Cameron 2016).

Representativeness – (i.e., is this type of site typical or unusual) In the consultant’s opinion, the archaeological materials assessed are typical or representative of small and large diffuse lithic scatters. Given that stone technology creates a great deal of detritus over time, one should not be surprised to find some indication of it anywhere on relic shorelines in this region.

Site Type/Function – The sites are situated on former shorelines and are probably campsites and/or workshops.

Age – The association of these sites with the earliest postglacial relict shoreline suggests a geochronological date of 8,500 to 10,500 Before Present (BP).

Rarity – The early postglacial time period is poorly known everywhere in Ontario, in part because the early postglacial Great Lakes shorelines are now submerged. In the Ottawa Valley, on the other hand, the major shorelines of the Champlain Sea and the ancestral Ottawa River are available for sampling as “relic shorelines” and “fossil islands”. Although systematic survey in the Ottawa Valley is relatively recent, the consultant has encountered similar lithic scatters on all the major relic shorelines, where he has sampled. Although all archaeological deposits are rare phenomena (and older deposits are more rarely preserved than recent ones) sites like those encountered in the NSDF Project site, may not be especially rare in this region, only rarely recorded.

Depositional Integrity – Sites with good depositional integrity exhibit buried cultural features (e.g., hearths, pits, and post molds) and artifacts remains that are, more-or-less, left as they were. At the excavations on the NSDF Project site, however, there were no cultural features and no apparent pattern in the horizontal or vertical distribution of the artifacts. The parent material throughout is deep deltaic sand, stony and rocky in places, and “pit and hummock” terrain is common. As a result, there has been considerable surface mixture.

Preservation of Organics – No organic materials or cultural features were observed, which is not surprising given the age of the deposit and the acidic and excessively well-drained nature of the soil. Bones from food remains do not preserve well in such conditions and are rarely preserved in Archaic period sites.

Artifact and Feature Frequency and Density – the frequency and density of artifacts is generally low, with the exception of the concentrations where test excavations are under way. There are no chronologically diagnostic artifacts present. The artifact assemblage consists of expedient or informal tools made from locally available raw material.

Human Remains and Burials – None were observed. One would not expect bones or burials to be preserved in these conditions.

Deeply Buried Archaeological Material – The test excavations have assessed only the upper 10 to 15 cm of soil. There is a chance that archaeological material may be deeply buried.

The standards and guidelines present criteria and indicators to evaluate cultural heritage value and interest (OMTC 2011:60-61, Table 3.2). These guidelines are described as follows as to their applicability to the NSDF Project site.

Cultural Heritage Value – The archaeological deposits at the NSDF Project site provide some information to advance our knowledge of settlement patterns during the early postglacial period and they provide a glimpse into the material culture of the ancestors of modern First Nations, specifically the Anishinabe. Algonquin oral history is based on a concept of the postglacial period and these sites are associated with “fossil islands” (Swayze and Cameron 2016).

Scientific Value – The sites in the vicinity of the NSDF Project have scientific value, because of their rarity and age (Swayze and Cameron 2016). Nevertheless, their scientific value is compromised by: poor depositional integrity, lack of organic artifact and cultural feature preservation, low artifact productivity, and absence of diagnostic artifacts. On the other hand, recent advances in lithic artifact study have found that use wear studies of stone tool collections can provide insight into past activities. High magnification surface analysis of stone tools is now advanced enough that organic residues such as lipids or resins have been found on the stone artifact surfaces. And organic samples as small as a single spore have been radiocarbon dated.

Value to a Community – Different communities may perceive the cultural value or interest of an archaeological site in various ways. Thus, it can be expected that First Nations would perceive these sites and artifact collections to have cultural value and interest (Swayze and Cameron 2016).

Value as a Public Resource – This refers to the ability of an archaeological resource to enhance the public's understanding and appreciation of Ontario's past. The criteria include potential for public use for education, recreation or tourism and the indicators of a suitable archaeological site are that it can be made accessible to tourists, local residents or school groups, and can be incorporated into local education, recreation or tourism strategies and initiatives. The sites in the vicinity of the NSDF Project have no potential in this respect because Stage 4 protection is not a realistic expectation. However, there may be places in CRL where these kinds of programs could be carried out in partnership with First nations (Swayze and Cameron 2016).

In summary, the archaeological sites encountered in the NSDF Project site, may not be especially rare in this region, only rarely recorded. There are no chronologically diagnostic artifacts or human remains or burials present. However, it can be expected that First Nations would perceive these sites and artifact collections to have cultural value and interest. Stage 4 Work to manage significant artifacts identified and confirmed in Stages 2 and 3 is expected to take place in 2017.

5.9.4.3 Traditional Land and Resource Use by First Nation and Métis Communities

5.9.4.3.1 Methods

First Nation and Métis interests considered are any First Nation and Métis interests that have been expressed to CNL during engagement with First Nations and Métis peoples as per CNL's Aboriginal Engagement Report (CNL 2016). As the proposed undertaking occurs within the general area of the Algonquins of Ontario (AOO) Settlement Boundary it is assumed that Algonquin of Ontario citizens continue to practice traditional land use activities throughout this region. Information on traditional land use activities by First Nation and Métis communities has been drawn from: existing studies and reports; formal and informal consultation activities; and general knowledge of the region and Algonquins of Ontario.

5.9.4.3.2 Results

The NSDF Project occurs within the general area of the Algonquin Land Claim. While use of the area around the CRL property by other First Nation and Métis communities is not certain, Algonquin traditional use has occurred for a very long period of time. In the Aboriginal Background Information Report to the Forest Management Plan for the Ottawa Valley Forest 2011 to 2021 it was indicated that:

> "Since the 1700's the Algonquins were known to spend the majority of the year occupying the different parts of the Ottawa Valley hunting, fishing, trapping and gathering among other things. These activities necessitated use of timber and other resources." (Ottawa Valley Forest 2011a)

The Algonquins of Ontario website describes the importance of traditional harvest:

> "The harvesting of flora and fauna for food and trade has been integral to the Algonquin way of life since time immemorial. These practices embody an inherent respect for the environment and a fundamental commitment to the sustainable management of resources, which has been passed from generation to generation.

> The AOO are comprised of ten Algonquin communities, including the Algonquins of Pikwàkanagàn First Nation, Antoine, Kijicho Manito Madaouskarini (Bancroft), Bonnechere, Greater Golden Lake, Mattawa/North Bay, Ottawa, Shabot Obaadjiwan, Snimikobi and Whitney and Area.
>
> The rights of Aboriginal people in Canada to engage in traditional activities, including the harvesting of wildlife, fish, migratory birds and plants, is recognized by the Constitution Act, 1982 and upheld by the Supreme Court of Canada. As stewards of our ancestral lands, the AOO recognize the importance of exercising this right in a responsible manner." (AOO 2016)

The AOO have further re-iterated the importance of traditional harvest in their Agreement-In-Principle with the Governments of Ontario and Canada. In Chapter 8 it is indicated that:

> "The Final Agreement will provide that Beneficiaries have the right to Harvest Fish, Wildlife, Migratory Birds and Plants for Domestic Purposes throughout the year within the Settlement Area as further described in this Chapter." (Algonquins of Ontario, Government of Ontario, Government of Canada 2016).

As indicated in the quotation above the intent of such harvest is for domestic purposes and not for commercial purposes (AOO 2016). It is likely that First Nation and Métis communities and possibly the ancestors of the modern-day Algonquins living in the Ottawa Valley undertook traditional activities, such as hunting that would have likely included lands that are currently under federal government control. Archaeological investigations for the NSDF Project have discovered artifacts from CaGi-40 the Early Archaic Period site (i.e., 6,000 to 10,000 years before present; Swayze and Cameron 2016).

5.9.4.3.2.1 Trapping

Trapping in Ontario occurs on licenced traplines on Crown land that are administered by the MNRF. There are approximately 50 licenced trapline areas in the Ottawa Valley Forest, which is slightly over 800,000 ha (Ottawa Valley Forest 2011a). Targeted species include beaver (*Castor canadensis*), fisher (*Martes pennant*), and marten (*Martes americana*; Ottawa Valley Forest 2011b). Trapping of fur bearing animals was a traditional and modern day land and resource use activity practiced by First Nation and Métis communities in the Ottawa Valley. The right to trap furbearing animals is outlined in Section 8.3.24 of the Algonquins of Ontario Agreement-In-Principle (Algonquins of Ontario, Government of Ontario, Government of Canada 2016). The inclusion of such a chapter indicates the importance of trapping as a cultural activity to the AOO.

There are two traplines near the CRL property PE025 and PE002; however, the RSA is restricted to the CRL property, and land uses of the CRL property are prohibited due to restricted public access. It is possible but unconfirmed whether there is any trapping occurring on the adjacent Garrison Petawawa. There are no adjacent provincial crown lands to the CRL property. All adjacent lands appear to be patent lands and therefore trapping adjacent to the CNL property would only be occurring by landowners or with landowner permission. It is unknown whether trapping on these private lands is being undertaken by First Nation and Métis communities. It is noted that CNL contracts a trapper for managing nuisance beavers on the CRL property.

5.9.4.3.2.2 Hunting

Hunting is a popular activity in the Ottawa Valley Forest (Ottawa Valley Forest 2011c) and hunting was and is practiced by First Nation and Métis communities in the Ottawa Valley. Hunting today includes moose (*Alces alces*), elk (*Cervus canadensis*), white-tailed deer *(Odocoileus virginianus),* small game and waterfowl. The Algonquins of Ontario prepare an annual Algonquin Harvest Management Plan specifically to address the hunting of larger game including moose, elk and deer (AOO 2016). The harvesting of wildlife is outlined in section 8.3 of the Algonquins of Ontario Agreement-In-Principle (Algonquins of Ontario, Government of Ontario, Government of Canada 2016). The inclusion of such a chapter indicates the importance of hunting as a cultural activity to the AOO.

The RSA is restricted to the CRL property, and hunting within the CRL property is prohibited. It is possible that there is waterfowl hunting along the Ottawa River shoreline of the CRL property, but it is not known to occur and the habitat considered poor (Audet 2016, pers. comm.). There are no adjacent provincial crown lands to the CRL property. All adjacent lands appear to be patent lands and therefore hunting adjacent to the CRL property would only be occurring by landowners or with landowner permission. It is unknown whether hunting on these private lands is being undertaken by First Nation and Métis communities.

As described in Section 5.9.4.1.3.3, the CRL property is located with WMU 48. Targets for moose have been identified for Algonquin harvest in WMU 48 (AOO 2016). While there is no elk harvest in this WMU, it is expected that there is likely harvest of deer, small game and waterfowl in this management unit. While it is not confirmed, it is very likely that there are some Algonquins and possibly some other First Nation and Métis communities hunting within 10 km of the perimeter of the property. It would be expected that some First Nation and Métis communities in Quebec also hunt on the Quebec side of the Ottawa River. Likely the hunting of animals is similar to Ontario and targets moose, deer, small game and waterfowl.

5.9.4.3.2.3 Fishing

Fishing was a traditional and modern day land and resource activity practiced by First Nation and Métis communities in the Ottawa Valley. The Ottawa River was and is still used for sport and subsistence fishing. Fish species targeted would have likely included the same type of sport and subsistence fish that occur today such as Walleye, Smallmouth Bass and Northern Pike (AECL 2010). Historically, Lake Sturgeon (*Acipenser fulvescens*), suckers (*Catostomidae* spp.) and American Eel (*Anguilla rostrate*) would have also been likely taken. The harvesting of fish is outlined in Section 8.2 of the Algonquins of Ontario Agreement-In-Principle (Algonquins of Ontario, Government of Ontario, Government of Canada 2016). The inclusion of such a chapter indicates the importance of fishing as a cultural activity to the AOO.

The RSA is restricted to the CRL property, and fishing within the CRL property is prohibited; however, it is likely that there is fishing by First Nation and Métis communities on the Ottawa River in the vicinity of the CRL property. This fishing is likely a combination of both sport and subsistence fishing.

5.9.4.3.2.4 Gathering

Gathering a traditional and modern day land and resource use activity practiced by First Nation and Métis communities in the Ottawa Valley. The gathering of plants, berries, and mushrooms would have been for subsistence, medicines, crafts and other purposes. The harvesting of plants is outlined in Section 8.5 of the Algonquins of Ontario Agreement-In-Principle (Algonquins of Ontario, Government of Ontario, Government of Canada 2016). The inclusion of such a chapter indicates the importance of gathering as a cultural activity to the AOO.

Gathering is an activity that provides important links to cultural continuity and traditional way of life. The RSA is restricted to the CRL property, and gathering within the CRL property is prohibited; however, it is possible that there may be some gathering activities along the shoreline of the Ottawa River. First Nation and Métis communities also likely gather plant materials and other resources on crown lands throughout the Ottawa Valley Forest. However, as the land adjacent to the CRL property is patent land, gathering likely occurs at least a few kilometers away from the site.

5.9.4.3.2.5 Cultural Resources and Ceremonies

First Nation and Métis communities place a high degree of value on specific sites of cultural, historical, spiritual, social or ecological significance. These sites may have broader cultural significance related to the practice of formal or informal ceremonies at or near these sites.

A known site of significance on the CRL property is what is known as the Pointe au Baptême Site. According to historical record this sandy spit was where the Voyageurs baptized new members and where local Algonquin camped frequently in the early 20th century. According to a local informant there is a cemetery at the base of the peninsula. CaGi-7 was revisited in 2007 to record historical Wallace Cottage features and to mark the suspected cemetery with an ornamental fence. Pre-Contact stone artifacts have been reported, over the years, from eroded parts of the site.

Pointe au Baptême has a high management priority rating due to its historical association and the reported human burials. It is of interest to the Algonquin community and affords a view of Oiseau Rock across the River, which a sacred pictograph site. Pointe au Baptême has been previously disturbed where there is an access road turn around. Recreational boaters on the Ottawa River frequently use Pointe au Baptême as a picnic stop, however the white chain fence (signifying the location of the suspected burials) is not easily identifiable from the beach.

Given this information on the site, it is assumed the site is of cultural significance to First Nation and Métis communities and there may or may not be formal or informal cultural activities associated with it. The Pointe au Baptême Site is not within the footprint of the NSDF Project, but is on the CRL property and is within the RSA.

5.9.5 Project Interactions and Mitigation

5.9.5.1.1 Methods

This section describes the process by which interactions between NSDF Project components and activities and the land and resource use VCs were identified and evaluated. Potential effect pathways are identified and mitigations have been developed to eliminate and/or reduce potential adverse Project effects. A pathways analysis is used to focus the assessment on key interactions between the NSDF Project and the environment by evaluating the different effect pathways to determine if, after incorporation of mitigation, there is still potential for residual effects. Where effects will be adequately mitigated and are not forwarded for further analysis (i.e., secondary pathways,

or where mitigation will remove the pathway altogether), the reasons for concluding the assessment at this stage are articulated. Primary pathways that may lead to residual effects after incorporation of mitigation are further characterized in subsequent subsections of the assessment. As such the ‘Project Interactions and Mitigations’ section helps to focus the remainder of the assessment on those interactions (effects pathways) likely to result in residual adverse effects.

The first part of the analysis is to identify the potential effects pathways for all stages of the NSDF Project. The next step in the analysis is the development of environmental design features and mitigation practices that could be incorporated into the NSDF Project to eliminate and/or reduce effects to land and resource use VCs. These measures include environmental design features, environmental best practices, and management policies and procedures. Environmental design features and mitigation were developed through an iterative process between the engineering and environmental teams, combined with input from project-specific engagement with other interested parties. The design features and/or mitigation activities were selected considering their effectiveness for implementation and maintenance, and their appropriateness within the context of the identified effect pathways.

After incorporation of mitigation, potential pathways were evaluated into the following categories using scientific knowledge, logic, experience with similar developments, and the effectiveness of environmental design features and mitigation:

- **No pathway –** pathway is removed by environmental design features or mitigation such that the NSDF Project would not be expected to result in a measurable environmental change to measurement indicators identified for land and resource use VCs relative to Base Case values, and therefore would have no residual effects to land and resource use VCs.
- **Secondary pathway –** the pathway could result in a measurable minor change to measurement indicators identified for land and resource use VCs, but would have a negligible residual effect on land and resource use VCs relative to Base Case values and is not expected to contribute cumulatively to other NSDF Project effects or to the effects of other past, present or reasonably foreseeable developments to cause a significant effect.
- **Primary pathway –** the pathway is likely to result in an environmental change to measurement indicators identified for land and resource use VCs relative to the Base Case that could contribute to residual effects to socio-economic VCs.

Environmental design features and mitigation that have been or could be incorporated into the NSDF Project to eliminate and/or reduce adverse effects to land and resource use VCs were considered. Potential pathways that were completely removed due to implementation of environmental design or mitigation were not assessed further. Pathways that were assessed to be secondary and demonstrated to have a negligible residual effect to land and resource use VCs through quantitative and qualitative evaluation of the pathway were also not advanced for further assessment. Primary pathways were carried forward for more detailed quantitative and qualitative effects analysis to characterize the residual effects of the NSDF Project on land and resource use VCs.

5.9.5.1.2 Results

The pathways analysis for the land and resource use VCs is presented in Table 5.9.5-1.

Table 5.9.5-1 Pathways Analysis for the Land and Resource Use Valued Components

Project Activity	Valued Component	Effects Pathways	Management Practices and Mitigation Actions	Pathway Assessment
Construction and Operation	Land and Resource Tenures and Other Registered Interests (i.e., land use designations, mining and aggregates, forestry and agriculture.	Change in access to or availability of tenured land use opportunities and other registered interests	Access to the RSA is restricted; therefore, no mining, aggregate, forestry, or agricultural activity will be affected by the Project.	No Linkage
Construction and Operation	Outdoor Tourism and Recreation (i.e., parks and protected areas, fishing, hunting, trapping and non-consumptive tourism and recreation).	Changes in access to or quality and quantity of outdoor tourism and recreation activities	Access to the RSA is restricted; therefore, therefore, no parks or protected areas, hunting, fishing or trapping activities will be affected by the Project	No Linkage
Construction	Archaeological Sites	Ground disturbance from the NSDF Project during construction may cause disturbance or destruction to archaeological sites.	■ Implementation of CNL's Archaeological Master Plan and Cultural Resource Management (CRM) program. ■ Should previously undocumented archaeological resources be discovered, CNL will suspend construction immediately and will engage a licensed consultant to carry out archaeological fieldwork, in compliance with Sec. 48 (1) of the *Ontario Heritage Act*. ■ If any human remains are identified during construction, CNL will immediately notify the police or coroner and the Registrar of Cemeteries, Ministry of Small Business and Consumer Services. In addition, immediate notification to First Nation and Métis communities or groups.	No Linkage
Construction and Operation	Traditional Land and Resource Use by First Nation and Métis Communities - Trapping	Changes in access to trapping activities or quality and quantity of trapping activities	Access to the RSA is restricted; therefore, there are no trapping activities completed within the RSA.	No Linkage
Construction and Operation	Traditional Land and Resource Use by First Nation and Métis Communities - Hunting	Changes in access to hunting activities or in the quality and quantity of hunting activity	Access to the RSA is restricted; therefore, there are no hunting activities completed within the RSA.	No Linkage
Construction and Operation	Traditional Land and Resource Use by First Nation and Métis Communities – Fishing	Changes in access to fishing activities or in the quality and quantity of fishing activities	Access to the RSA is restricted; therefore, there are no fishing activities completed within the RSA.	No Linkage

Table 5.9.5-1 Pathways Analysis for the Land and Resource Use Valued Components

Project Activity	Valued Component	Effects Pathways	Management Practices and Mitigation Actions	Pathway Assessment
Construction and Operation	Traditional Land and Resource Use by First Nation and Métis Communities - Gathering	Changes in access to gathering activities or in quality and quantity of gathering activities	Access to the RSA is restricted; therefore, there are no gathering activities completed within the RSA.	No Linkage
Construction and Operation	Traditional Land and Resource Use by First Nation and Métis Communities – Cultural Resources and Ceremonies	Changes in access to cultural resources for ceremonial purposes	The one existing site of cultural significance (i.e., Pointe au Baptême) with access will continue to be permitted.	No Linkage

No Linkage Pathways

An interaction may have no linkage to environmental effects if the activity does not occur, or if the interaction is removed by mitigation so that the NSDF Project results in no detectable change in measurement endpoints, and subsequently, no residual effect to land and resource use VCs. The following pathways are anticipated to have no linkage to residual effects to land and resource use VCs, and will not be carried through the residual effects assessment.

- **Change in access to or availability of tenured land use opportunities and other registered interests**
- **Changes in access to or quality and quantity of outdoor tourism and recreation opportunities**

The NSDF Project is located entirely within the CRL property (i.e., RSA), which is located on federal lands. Therefore, aside from the operations and activities undertaken by CNL, other land uses of the CRL property are prohibited due to restricted public access. Consequently, there are no mining, aggregate, or agricultural activities occurring within the RSA that have the potential to be disturbed. Although the NSDF Project overlaps the Ottawa Valley Forest FMU, the RSA does not overlap any active agreement forest areas; no commercial forestry activities are not permitted within the RSA. In addition, there are no municipal, provincial or national parks or conservation reserves, ANSIs or natural heritage systems, or tourism establishment areas located within the land and resource use RSA to be disturbed.

Although the NSDF Project overlaps large FMZ, WMU, trapline and baitfish harvest areas where hunting, trapping and fishing take place, the RSA is defined by the CRL property boundary and consumptive commercial or non-commercial land and resource use is prohibited. Moreover, the predicted residual effects of the NSDF Project on groundwater, surface water, air quality and terrestrial and aquatic habitat are negligible to low in magnitude and do not exceed the boundaries of the RSA (i.e., the CRL property boundary), therefore, no effects on land users beyond the property boundary are expected.

Overall, there are no anticipated residual effects on continued land and resource opportunities. No further assessment or characterization of residual effects is undertaken for the land and resource use VCs.

- **Ground disturbance from the NSDF Project during construction may cause disturbance or destruction to archaeological sites.**

There are no effects anticipated to archaeological resources as most mitigation measures for archaeological resources are applied and completed in advance of ground disturbance activities. In 2008, CNL developed an Archaeological Master Plan that resulted in a formal Cultural Resource Management (CRM) program at CNL. The CRM program includes an archaeological potential model which assists in locating areas of archaeological potential, and a robust cultural resource inventory of heritage sites. To date, the CRM program at CRL has identified over 50 heritage sites that are registered with the OMTCS, within the CRL property. There are six archaeological sites previously recorded within 1 km of NSDF Project site, but none are located directly within the NSDF Project footprint.

The CRM program will be used to identify unanticipated archaeological resources and implement adaptive management. The archaeological assessment will be submitted to the Minister of Tourism and Culture as a condition of licensing in accordance with the *Ontario Heritage Act*. Should previously undocumented archaeological resources be discovered, CNL will suspend construction immediately and will engage a licensed consultant to carry out archaeological fieldwork, in compliance with Sec. 48 (1) of the Ontario Heritage Act. If any

human remains are identified during construction, CNL will immediately notify the police or coroner and the Registrar of Cemeteries, Ministry of Small Business and Consumer Services. Consequently, this pathway was identified as having no linkage to effects on archaeological resources and is not evaluated further in this assessment.

- **Changes in access to or the quality and quantity of traditional land and resource use activities – trapping, hunting, fishing, gathering and cultural ceremonies**

Although the NSDF Project overlaps large traditional territory harvest areas where hunting, trapping, fishing and gathering take place, aside from the operations and activities undertaken by CNL, other land uses of the CRL property are prohibited due to restricted public access. Moreover, the predicted residual effects of the NSDF Project on groundwater, surface water, air quality and terrestrial and aquatic habitat are negligible to low in magnitude and do not exceed the boundaries of the RSA (i.e., the CRL property boundary), therefore no effects on traditional land users beyond the property boundary are expected. Consequently, the NSDF Project is not expected to affect access to traditional trapping, hunting, fishing and gathering activities. There are no anticipated residual effects on continued land and resource opportunities. No further assessment or characterization of residual effects is undertaken for this VC. Traditional access to the Pointe au Baptême site along the Ottawa River will continue to occur and not be restricted because of the project.

Secondary Pathways

No secondary land and resource use pathways are identified as part of this assessment.

Primary Pathways

No pathways were identified as having a primary linkage to land and resource use VCs. As such, a residual effects analysis and assessment of significance is not required for land and resource use VCs.

5.9.6 Monitoring and Follow-up

Monitoring and follow-up programs are not specifically identified for land and resource use; rather, monitoring for environmental pathways noted above (i.e., for air quality, water quality and groundwater quality) will be implemented to verify effects predictions for land and resource use. Monitoring to verify effects predictions will be on-going during operations, closure and post-closure phased and the need for and duration of monitoring will be reviewed based annual review of monitoring data. This monitoring will be integrated into the CNL Environmental Monitoring Program. In addition, as part of CNL’s Public Information Program, CNL will continue to engage with local communities, municipalities, and First Nation and Métis communities. Follow-up programs for archaeological resources are anticipated to be minimal as most mitigation measures for archaeological resources are applied and completed in advance of ground disturbance activities. Monitoring will be used to identify unanticipated archaeological resources and apply adaptive management through the implementation of the Cultural Resource Management portion of the Environmental Protection Program. Should previously undocumented archaeological resources be discovered, CNL will suspend construction immediately and will engage a licensed consultant to carry out archaeological fieldwork, in compliance with Section 48(1) of the *Ontario Heritage Act*.

5.9.7 Conclusions

Valued components refer to environmental features that may be affected by a project and that have been identified to be of concern by the proponent, scientists, government agencies, First Nation and Métis communities, or the public (The Agency 2014). Land and resource use VCs were selected based on the potential for the NSDF Project to interact with the features of the land and resource use environment. In addition, VCs for traditional land and resource use were selected based on consideration of knowledge of traditional land and resource use practices that interact with the environment, Aboriginal and/or treaty rights, engagement. Land and resource VCs selected for this assessment include:

- land and resource tenures and other registered interests (land use designations, mining and aggregates, forestry and agriculture);
- outdoor tourism and recreation (parks and protected areas, fishing, hunting, trapping, non-consumptive tourism and recreation);
- archaeological sites; and
- traditional land and resource use by First Nation and Métis communities (i.e., trapping, hunting, fishing, gathering, and cultural resources and ceremonies).

The NSDF Project is located entirely within the CRL property (i.e., RSA), which is located on federal lands. Therefore, aside from the operations and activities undertaken by CNL, other land uses of the CRL property are prohibited due to restricted public access. As such, there are land and resource use tensures and other registered interests, or outdoor tourism and recreational areas occurring within the RSA that have the potential to be disturbed. Moreover, the predicted residual effects of the NSDF Project on groundwater, surface water, air quality and terrestrial and aquatic habitat are negligible to low in magnitude and do not exceed the boundaries of the RSA (i.e., the CRL property boundary), therefore no effects on traditional and non-traditional land users beyond the property boundary are expected. Traditional access to the Pointe au Baptême site along the Ottawa River will continue to occur and not be restricted because of the project. There are no effects anticipated to archaeological resources as most mitigation measures for archaeological resources are applied and completed in advance of ground disturbance activities. The CRM program will be used to identify unanticipated archaeological resources and implement adaptive management. Consequently, the NSDF Project is not expected to affect land and resource VCs.

This page intentionally left blank

5.10 Socio-economic Environment

Section 5.10 of the Environmental Impact Statement (EIS) for the Canadian Nuclear Laboratories (CNL) Near Surface Disposal Facility (NSDF) Project seeks to understand and characterize the potential residual effects of the NSDF Project and past, present, and reasonably foreseeable developments on the socio-economic environment. Potential effects on archaeology and cultural heritage are described in Section 5.9 Land and Resource Use. As part of the EIS, the following subsections present an assessment of the socio-economic effects of the NSDF Project.

5.10.1 Scope of the Assessment

The socio-economic assessment follows the overall environmental assessment approach and methods described in Section 5.1. The assessment is completed in the following key steps.

- **Step 1 – Identify Valued Components (VCs) and define the spatial boundaries, temporal boundaries, and assessment cases** for the socio-economic assessment (refer to Sections 5.10.2 Valued Components and Section 5.10.3 Assessment Boundaries). The VCs, assessment endpoints, and measurement indicators used to assess NSDF Project related changes to socio-economics; the spatial and temporal boundaries at which the assessment occurred; and, the assessment cases considered.
- **Step 2 – Describe the existing conditions** (refer to Section 5.10.4 Description of the Environment). Existing conditions in the local and regional areas are described, including the combined effects of previous and existing developments (Base Case). The existing environment represents the historical and current socio-community characteristics, including non-tangible features and the “built” environment.
- **Step 3 – Evaluate Project interactions and mitigation** (refer to Section 5.10.5 Project Interactions and Mitigation). Project components and/or activities with the potential to affect socio-economics are identified and mitigation developed to limit or avoid effects is presented. A pathways analysis is then used to focus further assessment on key interactions between the NSDF Project and the environment by evaluating the different effect pathways to determine if, after incorporation of mitigation, there is still potential to cause residual effects. Where effects are adequately mitigated and are not forwarded for further analysis (i.e., secondary pathways, or where mitigation will remove the pathway altogether), the reasons for concluding the assessment at this stage are articulated. Primary pathways that may lead to residual effects to socio-economics after incorporating mitigation are carried forward to Steps 4 for further analysis and residual effects characterization.
- **Step 4 – Present the methods and results of the residual effects analysis** (refer to Section 5.10.6 Residual Effects Analysis). This section outlines the methods used to predict and characterize residual effects to socio-economics from primary effect pathways. The analysis results are also presented including the characterization of incremental effects from the NSDF Project, as well as cumulative effects of the Project in combination with other reasonably foreseeable developments (if applicable).

- **Step 5 – Describe the level of certainty and management of uncertainty** (refer to Section 5.10.7 Prediction Confidence and Uncertainty). This purpose of this section is to evaluate the available literature and data used for the assessment, and describe the level of certainty that can be placed on predicted residual effects. This section will also identify how the uncertainty has been managed so that the effects are not underestimated.
- **Step 6 – Classify and determine the significance of the predicted residual effects** (refer to Section 5.10.8 Residual Effects Classification and Determination of Significance). Residual effects predicted from primary pathways are classified using a common set of criteria: direction, magnitude, geographic extent, duration, reversibility, frequency, and likelihood. A determination of the significance of the predicted residual effects from NSDF Project for the socio-economics VCs is made.
- **Step 7 – Identifying monitoring and follow-up** required to confirm effects predictions and address uncertainty (refer to Section 5.10.9 Monitoring and Follow-up).
- **Step 8 – Present a consolidated summary of conclusions and outcomes of the assessment** of residual effects on socio-economics (refer to Section 5.10.10 Conclusions).

Information and areas of interest raised by the public, communities of interest, regulators, and First Nation and Métis communities during engagement that influenced the scope of the socio-economic assessment are summarized in Table 5.10.1-1. Other general areas of interest and questions raised during the engagement that pertain to the socio-economics assessment (if any) are documented in Appendix 4.0-22 Formal Public Feedback.

Table 5.10.1-1: Summary of Areas of Interest Raised during Engagement Activities that Influenced the Scope of the Socio-economic Assessment

Area of Interest	How the Area of Interest Was Included in the Assessment
Will consideration be given to provide jobs or buy material, such as sand that could be delivered by large, to the closest full time residents to the site, in Sheenboro QC?	The industries that will supply the NSDF Project with goods and services (e.g., manufacturing, wholesale, transport) are anticipated to be concentrated in the County of Renfrew and in the City of Ottawa. Canadian Nuclear Laboratories will competitively procure material and services for the NSDF Project (see Section 5.10.6.2.1). The construction workforce is anticipated to be sourced from firms within the County of Renfrew and the Ottawa area. Canadian Nuclear Laboratories employment opportunities that may arise due to NSDF Project activities will be posted on the www.cnl.ca website (see Section 5.10.6.2.1).

5.10.2 Valued Components

Valued components refer to socio-economic and environmental features that may be affected by a project and that have been identified to be of concern by the proponent, scientists, government agencies, First Nation and Métis peoples, or the public (The Agency 2014). Socio-economic valued components (VCs) were selected based on the potential for the NSDF Project to interact with the features of the socio-economic environment. The VCs selected for assessing potential effects on socio-economic conditions are presented in Table 5.10.2-1.

Table 5.10.2-1: Valued Components for Socio-economic Assessment

Valued Component	Rationale for Selection
Labour Market	Local workforce and communities are interested in long-term employment opportunities that will be generated through the NSDF Project. Income generation is perceived as a Project benefit by local workforce, businesses, and communities.
Economic Development	The NSDF Project will contribute to local and regional economies, through direct procurement, as well as indirect investment in other business activities.
Government Finances	The NSDF Project will generate incremental tax revenues for all levels of government.
Housing and Accommodations	Potential in-migration of workers (and families) for the NSDF Project could increase the demand for permanent housing or temporary accommodations.
Services and Infrastructure	Potential in-migration of workers (and families) for the NSDF Project could increase the demand for community services (i.e., schools, community health, protection and emergency services) and community infrastructure (i.e., water supply and traffic).
Quality of Life	Project activities (i.e., changes in air quality, ambient noise, increases in traffic volume, and visual disturbances) could affect worker and local public quality of life.
Public Safety	Public safety is a concern near the NSDF Project. Hazards include heavy equipment operation and other hazards typical of industrial facilities.

Assessment endpoints are qualitative expressions used to assess the significance of residual effects on VCs and represent the key properties of the VC that should be protected for future generations. The assessment endpoint for the socio-economics VCs are presented in Table 5.10.2-2. Measurement indicators represent properties of the environment and VCs that, when changed, could result in or contribute to an effect on a VC. Measurement indicators can be used to monitor the success of mitigation and management programs. The assessment endpoints and measurement indicators associated with the socio-economic assessment are outlined in Table 5.10.2-2.

Table 5.10.2-2: Assessment Endpoints and Measurement Indicators for the Socio-economic Assessment

Valued Component	Assessment Endpoints	Measurement Indicators
Labour Market	Employment opportunities and income generation	■ Direct, indirect, and induced employment ■ Income generation ■ Training and skill development opportunities
Economic Development	Business and economic development opportunities	■ Direct goods and services purchased by types and number of suppliers and their location ■ Indirect supplier industry expenditures and output ■ Induced expenditures and output generated associated with household spending

Table 5.10.2-2: Assessment Endpoints and Measurement Indicators for the Socio-economic Assessment

Valued Component	Assessment Endpoints	Measurement Indicators
Government Finances	Contribution to Government finances	Government revenue generation
Housing and Accommodations	Housing and accommodation availability	■ Number of residents in local communities ■ Housing demand and supply
Services and Infrastructure	Community services and infrastructure availability and access	Education, health, protective and emergency services demand, use and supply
Quality of Life	Contribution to quality of life	Changes in air quality, ambient noise, increases in traffic volume, and visual disturbances (nuisance effects)
Public Safety	Protection of Public	Public exposure to physical hazards (note that chemical hazards and potential effects on human health are evaluated in Section 5.7 Ambient Radioactivity and Section 5.8 Human Health)

Assessment endpoints and associated measurement indicators for each socio-economic VC are further discussed below.

- **Labour Market:** The assessment endpoint of continuation of employment opportunities and income generation pertains to the incremental change that the NSDF Project will have on both direct local and regional income through direct employment and purchase of goods and services. It also considers the availability of persons with the required skills to satisfy the NSDF Project's labour needs during all project phases. The assessment endpoint will be influenced by the number of direct construction and operational positions required for the NSDF Project and the average wage/salary levels of these positions. The Project will also generate employment in goods and services supply (indirect employment) and may possibly lead to a small amount of induced employment from NSDF Project workforce expenditures. Training and skill development opportunities provided by the NSDF Project to the workforce and contractors/suppliers can contribute to the local labour force and local business community's skills and capacity.
- **Economic Development:** The assessment endpoint considers incremental expenditures for procurement requirements created by the NSDF Project and implications to the existing industry and business profile in the regional and local study areas. The measurement indicators used are the types and amount of goods and services required by the NSDF Project, and opportunities provided to local businesses.
- **Government Finances:** The NSDF Project will generate taxes in the form of personal and corporate income taxes, property taxes and various consumption taxes. These fiscal benefits generated by the NSDF Project can be compared to government revenue streams. The assessment endpoint of continuation of government finances will be influenced by the tax generation associated with the NSDF Project.
- **Housing and Accommodations:** Project-related effects on availability of housing and temporary accommodation are driven by potential project-induced changes in the size of local population and population characteristics (i.e., effect of population change on housing supply and demand). New NSDF Project employees (and in some cases their families) may require access to local housing and/or temporary accommodation during the construction phase.

- **Services and Infrastructure:** Project-related effects on availability of community services and infrastructure are driven by potential project-induced changes in the size of local population and population characteristics (i.e., effect of population change on demand of community services and infrastructure). The NSDF Project's effects on services and infrastructure are linked to Project-related direct use of services during construction and operational activities (e.g., transportation network). The NSDF Project's effects are also linked to incremental demand, the available capacity to accommodate additional pressure placed on services due to population growth, the ability of these services to meet the demands of the local population and the potential requirement for additional capital investment in services and infrastructure.
- **Quality of Life:** Project-related effects on quality of life are driven by potential project-induced changes in environment (i.e., changes in air quality, ambient noise, increases in traffic volume, and visual disturbances).
- **Public Safety:** The assessment endpoint for public safety addresses concerns related to hazards associated with the NSDF Project site during construction, operations, closure, and post-closure activities.

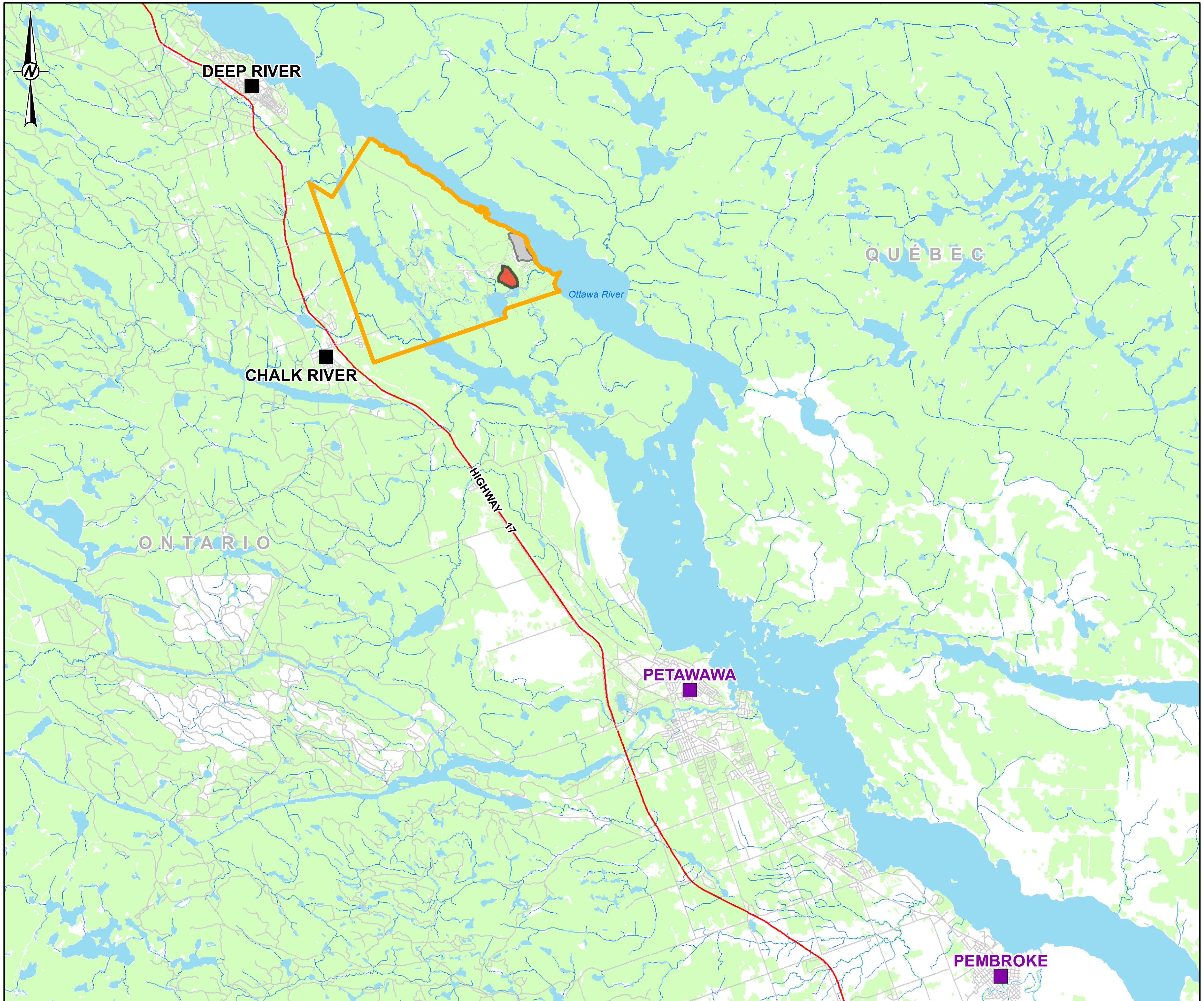
5.10.3 Assessment Boundaries

5.10.3.1 Spatial Boundaries

The spatial boundaries selected for the terrestrial biodiversity assessment were chosen because they permit description of existing conditions in sufficient detail to enable potential project-VC interactions and effects to be identified, understood, and assessed, including understanding and assessing the contribution of the NSDF Project to cumulative effects. The spatial boundaries selected for the socio-economic assessment are presented on Figure 5.10.3-1 and are described below.

- **The Site Study Area (SSA):** is defined as the NSDF Project footprint (i.e., where Project activities would be undertaken including the NSDF Project's proposed facilities, buildings and infrastructure).
- **The Local Study Area (LSA)**: is defined as the area within which there is potential for measurable effects to socio-economic VCs resulting from the proposed NSDF Project activities. The LSA includes the closest communities to the NSDF Project, specifically the Village of Chalk River (7 kilometres [km] west of the Chalk River Laboratories [CRL] property) and the Town of Deep River (10 km northwest of the CRL property; Figure 5.10.3-1). Mountain View, a settlement within the Municipality of Laurentian Hills, lies between Chalk River and Deep River off Highway 17. Wylie, a settlement that constitutes part of the Municipality of Laurentian Hills, is located 12 km northwest of the NSDF Project, near Mountain View. Wylie and Mountain View were not included in the assessment as data for these settlements are not available due to their small populations.
- **The Regional Study Area (RSA):** is defined as the area within which the potential effects of the NSDF Project may interact with the effects of other existing or reasonably foreseeable projects. The RSA is defined to include the communities of Petawawa and Pembroke (approximately 20 km and 35 km southeast of the CRL property) as it is anticipated that workforce and business opportunities within these communities may overlap with those required for CNL's Nuclear Power Demonstration (NPD) Closure Project.

This page left intentionally blank



LEGEND

- HIGHWAY
- ROAD
- RIVER/STREAM
- WATERBODY
- WOODED AREA
- SITE STUDY AREA (NSDF PROJECT SITE)
- CRL MAIN CAMPUS
- CRL PROPERTY
- LOCAL STUDY AREA COMMUNITY
- REGIONAL STUDY AREA COMMUNITY

2.5 0 2.5
1:140,000 KILOMETRES

REFERENCE(S)
1. BASEDATA ONTARIO MNRF 2016, CANVEC 2016, QUÉBEC MRNF 2016 AND CNL 2016
2. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY 2017)
3. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND JANUARY

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, ENVIRONMENTAL IMPACT STATEMENT
CHALK RIVER, ONTARIO

TITLE
SPATIAL BOUNDARIES SELECTED FOR THE SOCIO-ECONOMIC ASSESSMENT

CONSULTANT

Golder Associates

YYYY-MM-DD	2017-03-15
DESIGNED	SO
PREPARED	SO/JR
REVIEWED	MM
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	0.0	5.10.3-1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:
25mm

This page left intentionally blank

5.10.3.2 Temporal Boundaries

Temporal boundaries (i.e., project phases) establish the timeframe during which NSDF Project effects are assessed. The temporal boundary represents the timeframe during which project activities are actively occurring, and does include the duration of predicted residual effects. The duration of an effect is defined as the amount of time between the start and end of a Project activity or stressor (which is related to the project phases) plus the time required for the residual effect to be reversed. In some cases, a residual effect may be irreversible within the temporal boundaries of the Project (e.g., residual effect lasts for thousands of years). The following phases were identified for the NSDF Project.

- **Construction Phase**: includes site preparation and all activities associated with the construction of the NSDF. This phase includes activities such as installing the necessary supporting and/or ancillary facilities and NSDF infrastructure to facilitate NSDF operations, inactive commissioning and systems testing, and transportation of construction materials. Construction activities are expected take place from 2018 to 2020. The construction phase will require an average of 45 full-time equivalents, with a peak workforce of approximately 60 full-time equivalents.
- **Operations Phase**: includes all activities associated with the landfilling of waste receipt, waste placement, water management, wastewater treatment plant operations, vehicle movements into and from the NSDF Project site, and maintenance activities. The operations phase is expected to last approximately 50 years (i.e., 2020 to 2070) with an average labour force of 40 full-time equivalents, which is expected to be drawn from the existing CRL workforce.
- **Closure Phase:** includes activities necessary to complete the installation of the final cover and implementation of long-term monitoring. Closure activities are expected to start in 2070 and continue through to 2100, after which the NSDF Project will transfer into the post-closure phase.
- **Post-closure Phase:** has two discrete periods: Institutional Control and post-Institutional Control. The Institutional Control period includes implementation of both active and passive control throughout 2100 to 2400 (i.e., 300 years). During Institutional Control, groundwater monitoring and groundwater quality management will continue to demonstrate compliance with the safety case assumptions. Post-institutional Control occurs after year 2400 and continues indefinitely.

For the purposes of the socio-economic assessment, effects during the construction phase are expected to have the greatest magnitude; as such NSDF Project-related effects are assessed for the construction phase only. Effects to the socio-economic VCs during the operations, closure and post-closure phases are expected to be less than effects predicted during the construction phase of the NSDF Project.

5.10.3.3 Assessment Cases

The assessment cases considered in the socio-economic assessment include the Base Case and the Application Case.

- **Base Case –** This scenario represents existing conditions and characterizes effects from previous and existing developments and activities. The Base Case reflects the effects of existing infrastructure and services in the area, such as forestry, transportation, agricultural, mining, and residential and recreational development. Current effects from the existing CRL facilities and operations are considered part of the Base Case. In addition, the expansion of the Garrison Petawawa Canadian Armed Forces Base is expected to begin in 2015 and end in 2017 (Government of Canada 2016c); therefore, the expansion is also considered as part of the Base Case.
- **Application Case –** This scenario represents the effects of the Base Case combined with the predicted effects from the NSDF Project. The workforce is the largest during the construction phase, and although the operations phase is expected to last approximately 50 years the operations labor force is expected to be drawn from the existing CRL workforce. As such, the Application Case only considers the construction phase as the bounding phase for socio-economic effects of the NSDF Project.
- **Reasonably Foreseeable Developments (RFD) Case** – This scenario represents the effects of residual adverse effects of the Application case combined with other reasonably foreseeable projects in the socio-economic RSA. Canadian Nuclear Laboratories' NPD Closure Project is anticipated to overlap temporally and spatially with the NSDF Project. Decommissioning of the NPD Project is expected to occur from 2018 to 2020 and it is anticipated that workforce and business opportunities within Town of Petawawa and City of Pembroke will overlap with those required for the NSDF Project.

5.10.4 Description of the Existing Environment

This section presents an overview of the socio-economic setting as relevant for the assessment of the NSDF Project. It describes the existing conditions (i.e., Base Case) against which potential changes from the NSDF Project are compared and evaluated.

5.10.4.1 Methods

Baseline information was collected from a range of information sources and analyzed to submit a profile for the social and economic conditions in the LSA and RSA. Baseline information was collected from the following sources:

- Statistics Canada census and national household survey;
- municipal and territorial government websites;
- local service provider websites;
- regional tourism authority sources; and
- e-mail and telephone communications with key informants (i.e., Fire Chiefs).

Existing socio-economic conditions in the LSA and RSA are described, as relevant for the assessment of potential NSDF Project effects on:

- socio-community characteristics (e.g., existing and projected population and demographic data, housing and accommodation, services and infrastructure, and quality of life);
- economic characteristics (e.g., labour market, economic development and government finances); and
- land used by businesses (e.g., existing land developments, outdoor recreation).

5.10.4.2 Results of Socio-community Characteristics

The NSDF Project is located on CRL property in Renfrew County, approximately 10 km southeast of the Town of Deep River, 9 km northwest of the Federal Department of National Defence Garrison Petawawa, and 7 km east of the Village of Chalk River (Figure 5.10.3-1). The land is characterized by deciduous and coniferous forest and the Ottawa River, which forms the northeastern boundary of the Town of Deep River. The CRL property is located in the Allumette Lake and Lac Coulonge reach of the Ottawa River, which extends approximately 90 km between La Passe and the Des Joachims Dam. The distance from the centre of the NSDF Project site to the closest point on the Ottawa River is approximately 1 km.

The Village of Chalk River is approximately 5 km southwest across Highway 17. The village is part of the amalgamation of communities that form the Town of Laurentian Hills, and is connected directly to the CRL property through Plant Road off Highway 17 (County of Renfrew 2016a). The majority of the population of the Town of Laurentian Hills resides in the urban settlement areas of Chalk River, Rolphton and Point Alexander along the Highway 17 corridor (Tunnock Consulting Ltd. 2010). Due to the close proximity to the CRL property, the Town of Laurentian Hills is considered within the 9 km primary zone[1] of the CRL reactor stack (CNL 2016).

The Town of Deep River is the largest community near the NSDF Project site, approximately 10 km northwest of the CRL property. Established as a company town for Atomic Energy of Canada Limited (AECL) in the 1940s, Deep River is the location of the largest nuclear research facility[2] in Canada (CRPD 2012). The Town of Deep River contains the built-up town site, the CRL property and federally-owned forested lands. As the second largest employer in the County of Renfrew, behind the Canadian Forces Base (CFB) Petawawa, CNL provides large public sector employment with above average wages for the area (CRPD 2012). In 2013, CRL employed approximately 3,285 people and Base Petawawa employed around 7,000, with base personnel becoming an important source of new residents for the community (AECL 2013; County of Renfrew 2013). The Pembroke Census Agglomeration (CA) is approximately 35 km southeast of the CRL property, and is the largest community and the administrative headquarters of Renfrew County. Pembroke is the largest commercial centre between Ottawa and North Bay and provides many commercial services to local area residents in the Ottawa Valley and surrounding regions (City of Pembroke 2016).

---

[1] As mandated by regulations set by the Canadian Nuclear Safety Commission, all permanent residents within the 9 km Primary Zone of a nuclear reactor in Canada are to be provided with potassium iodide tablets (Laurentian Hills 2015). The communities within 9 km of the Chalk River Laboratories are those who live in the following areas of Laurentian Hills and Deep River: Balmer Bay Road, Mountain View Subdivision, Village of Chalk River, Highway 17 between Plant Road and Wylie Road, and any directly adjoining roads near Highway 17 within the above range. This assessment focuses only on the communities of Deep River and Laurentian Hills as they have the potential to experience socio-economic effects.

[2] All licenses for the operation of Chalk River Laboratories were transferred from Atomic Energy of Canada Limited to Canadian Nuclear Laboratories Ltd on November 3, 2014 (Government of Canada 2016).

5.10.4.2.1 Population, Demographics and Mobility

Between 2006 and 2011, the population in the Town of Deep River (4,193) had a slight decrease (0.5%) while the population in the Municipality of Laurentian Hills (2,811) increased slightly during the same period (0.8%), as shown in Table 5.10.4-1. The Town of Deep River had an almost equal number of males and females, with 2,100 males and 2,095 females in 2011. The Municipality of Laurentian Hills had slightly more males than females, with 1,470 males and 1,340 females (Statistics Canada 2012a,b).

Deep River has a considerably older median age of 47.5 compared to the 41.1 median age of Municipality of Laurentian Hills and 40.4 median age for the province of Ontario (Statistics Canada 2012a,c). This may be due to the presence of retirees from CRL. The Town of Deep River reported that most retirees remain in the town and replacement workers come from outside the community (CRPD 2012). Both communities experienced greater numbers of intraprovincial migration within the last five years, compared to interprovincial migration, which is likely due to the highly specialized workforce needed for CRL. In 2011, the Town of Deep River and the Village of Chalk River housed the two largest populations of employees from CRL (893 and 190 respectively; County of Renfrew 2011). The skilled workforce required in the nuclear industry is based predominantly in Ontario as most of Canada's nuclear reactors currently in full commercial operation, are in Ontario (Government of Canada 2016a).

Like the aging trends seen in the County of Renfrew and the Province of Ontario, the Town of Deep River is aging as a result of the "baby boom" cohort. Between 2001 and 2011, all age categories in the town except for the under-45 category increased (Jp2g Consultants 2015a). The highest rate of growth in that period was seen in the 50 to 54 and 55 to 59 age ranges (16.7% and 25.7%), while the under 45 age range decreased (-7.4%).

In 2012, Deep River projected to have a population of 4,455 in 2015 and 4,528 in 2020 due to the ongoing growth at Base Petawawa and stability at CRL (CRPD 2012). A greater proportion of the Municipality of Laurentian Hills identified as First Nations and Métis peoples (12.5%) compared to the Town of Deep River (7.8%). Table 5.10.4-1 presents the population and demographic characteristics of the LSA.

In the RSA, the Petawawa Census Agglomeration (CA)[3] had a population of 15,988 and the Pembroke CA[4] had a population of 24,017 in 2011. Both communities have experienced population growth since 2006 growing at a rate of 9.1% and 3.5%, respectively. The high rate of population growth in Petawawa is due to increased personnel at CFB Petawawa, with soldiers returning from missions abroad with the end of active combat in Afghanistan (Canada.com 2012). The presence of a large number of military personnel and their families also provides an explanation for the lower median age of 30.4 years, which is lower than the other LSA and RSA communities, and the Province. Similarly, both interprovincial and intraprovincial migration was higher in Petawawa, as military personnel come from across the province and Canada, while in Pembroke intraprovincial migration was in line with trends seen in Laurentian Hills, Deep River and the Province. There are more women than men in Pembroke, which is a trend that is not seen anywhere else in the LSA or RSA, but is the case for Ontario. There is also a relatively high First Nations and Métis population (9.3%) living in Pembroke (Statistics Canada 2013e,f).

[3] The Petawawa Census Agglomeration (CA) is defined by Statistics Canada as being the Town of Petawawa, Canadian Forces Base Petawawa and surrounding areas. Data provided in this report are for the Petawawa CA.

[4] Pembroke Census Agglomeration (CA) is defined by Statistics Canada as being the City of Pembroke and surrounding regions. Data provided in this report are for the Pembroke CA.

Table 5.10.4-1: Population and Demographic Characteristics of the LSA, RSA and the Province of Ontario

	Municipality of Laurentian Hills	Town of Deep River	Petawawa Census Agglomeration	Pembroke Census Agglomeration	Province of Ontario
Total Population 2011	2,811	4,193	15,988	24,017	12,851,821
Total Population 2006	2,789	4,216	14,651	23,195	12,160,282
2006 to 2011 population change (%)	0.8	-0.5	9.1	3.5	5.7
Median Age of the population	41.1	47.5	30.4	45.2	40.4
Males	1,470	2,100	8,650	11,530	6,263,140
Females	1,340	2,095	7,335	12,485	6,588,685
% of population with Aboriginal identity	12.5%	7.8%	6.7%	9.3%	2.3%
Intraprovincial migrants within the last 5 years	580	810	2,785	2,715	1,337,130
Interprovincial migrants within the last 5 years	175	75	2,530	895	177,605

Statistics Canada 2012a,b,c,d,e,f

5.10.4.2.2 Education

The population in the LSA are a highly educated and skilled workforce. In 2011, approximately one-third (33.6%) of the population of Deep River reported that they had attained a university level education or above, which was higher than the rates for the county and the Province of Ontario (9.3% and 23.4%; Statistics Canada 2013a,b,c). Approximately a quarter (25.4%) of the population in Deep River reported that they had attained a college or other non-university level certificate or diploma. In the Municipality of Laurentian Hills, approximately one-third (32.0%) had attained a high school certificate as their highest level of educational attainment (Statistics Canada 2013b). In comparison, 13.0% and 6.6% in the Municipality of Laurentian Hills and the Town of Deep River had attained an apprenticeship, trades certificate or diploma. This is indicative of the type of jobs available to the residents of the LSA as a result of the NSDF Project, where education above a high school level is a requirement of CNL.

In the RSA, approximately 37.8% of the population in Petawawa and 29.5% of the population in Pembroke had a high school certificate or equivalent as their highest level of education achieved. While the percentage of the population with a university degree or equivalent was lower than the provincial average, a larger percentage of people (21.7% in Petawawa CA and 22.6% in Pembroke CA) from these communities had attained a college or non-university certificate or diploma than the provincial average (19.8% in Ontario) (Statistics Canada 2011a,b).

5.10.4.2.3 Land Use

The majority of land in the Town of Deep River's municipal boundary is owned by CNL, which falls under federal jurisdiction. Deep River is currently composed of a downtown core (i.e., commercial, institutional, high density residential), including:

- the marina and public waterfront;
- stable residential areas;
- the Highway 17 commercial corridor;
- large-lot estate residential;
- a large open space and parkland network (including the Four Seasons Conservancy trail system); and
- undeveloped areas to the west and east of the developed portion of the Town (Jp2g Consultants 2015a).

With the exception of existing operations and activities undertaken by CNL, other land uses of the CRL property are prohibited due to restricted public access. The CRL property is not used for traditional purposes by First Nation and Métis people (CRL 2013a). Land use in the area surrounding the CRL property consists primarily of forestry, recreation and tourism, with limited agriculture, trapping and mining (CRL 2013b). The nearest area of notable agriculture and dairy farming is located outside the LSA, 15 km southeast on the Quebec side of the Ottawa River and 35 km southeast on the Ontario side.

The Municipality of Laurentian Hills is a sparsely populated area. Outside of the village and hamlet settlement areas, most land within the municipality is rural land (Tunnock Consulting Ltd. 2010). With a population density of 4.4 people per square kilometre (km^2), the majority of residents in the municipality reside along the Highway 17 corridor and along the shoreline of the Ottawa River (Statistics Canada 2012b; Tunnock Consulting Ltd. 2010). A business park of approximately 9.7 hectares (ha) of vacant lands is located at the southeast end of Chalk River (Tunnock Consulting Ltd. 2010).

Outdoor recreational activities in the Municipality of Laurentian Hills and the Town of Deep River include hiking, biking, snowmobiling, and skiing trails as well as swimming, sport fishing and boating along the Ottawa River (Ottawa Valley 2016; Laurentian Hills 2016a). Of particular note is the 400 ha reserve located east of the Town of Deep River, the Four Seasons Conservancy, which is highly valued by the town's residents for outdoor recreation (Deep River 2013).

In the RSA, both the Municipality of Petawawa and the City of Pembroke are urban centres that are more densely populated than the LSA. The CFB Petawawa is located in the northwest quadrant of Petawawa's central business district and provides retail services to military personnel and their families. The City of Pembroke is also a services and retail hub to nearby suburbs and communities. Recreational activities such as cycling and water-based activities take place in both communities along the shores of the Ottawa River (Petawawa 2016a; Pembroke 2016a).

5.10.4.2.4 Labour Market

The two largest employers within the LSA are the Canadian Forces Base Petawawa and AECL (CRPD 2012; Renfrew County 2013). The CFB Petawawa is located in the RSA near the Town of Petawawa and employs nearly 7,000 military and civilian personnel (Petawawa Morale and Welfare Services 2016-2017). Chalk River Laboratories is the second largest employer in the region. As of December 2013, CRL employed approximately 3,285 full-time employees; however their operations are projected to slow down over the next several years (AECL 2013). In addition, some of the historically larger employers in the region, such as the Government of Canada's Petawawa Research Forest, located east of Chalk River between CRL and the Canadian Forces Base Petawawa have ramped down operations and employment in the region (The Forest Research Partnership 2016).

Between 2006 and 2011, the Municipality of Laurentian Hills's unemployment rate decreased from 8.6% to 2.6%. (Table 5.10.4-2). During the same period, the Town of Deep River's unemployment rate increased slightly (from 4.4% in 2006 to 5.2% in 2011). Based on the most recent data available, both communities in the LSA have lower unemployment rates (5.2% and 2.6%) compared to the County of Renfrew (7.8%) and the Province of Ontario (8.3%; Statistics Canada 2013a,b,c,d). While the LSA communities' participation rates were slightly lower than the county and provincial rates, this is likely due to the higher median ages found in the LSA communities, which indicates a larger percentage of retirees present.

Table 5.10.4-2: Select Labour Market Characteristics (2011)

Community	Population Age 15 and Over	In the Labour Force	Employed	Unemployed	Participation Rate (%)	Unemployment Rate (%)
Town of Deep River	3,580	2,010	1,905	105	56.1	5.2
Municipality of Laurentian Hills	2,300	1,355	1,320	35	58.9	2.6
Petawawa CA	12,180	9,010	8,510	500	74.0	5.5
Pembroke CA	20,435	12,085	11,215	870	61.8	7.2
County of Renfrew	82,720	51,785	47,770	4,020	62.6	7.8
Province of Ontario	10,473,670	6,864,990	6,297,005	567,985	65.5	8.3

Statistics Canada 2013a,b,c,d,e,f.

An economic overview for Deep River found that in 2014, a large proportion (41% or 1,061 out of 2,574 jobs) of the town's employment base was in the professional, scientific and technical services industry, followed by retail, accommodations and food services, and health care and social assistance (Jp2g Consultants 2015a). While the highest growth is anticipated in the service industries, growth in the professional, scientific and technical industries is largely linked to the operations of CNL, its contractors, and other businesses that provide services directly to the company. The Town of Deep River strategized that diversification of this industry to other sources of businesses will benefit the local economy and make it more resilient in the event of organizational and operational changes at CNL (Jp2g Consultants 2015a).

There is a very limited number of construction firms in the Town of Deep River and Municipality of Laurentian Hills. In 2014, only 38 out of 2,574 jobs (1.5%) in Deep River were in the construction industry (Jp2G Consultants 2015a). The few construction companies that do operate in the LSA communities focus primarily on home renovation (Yellow Pages 2016a,b).

In Petawawa, the labour force participation rate is higher (74%) than the provincial average and the unemployment rate (5.5%) is lower than the provincial average (Canada.com 2012). The CFB Petawawa employees and the population employed through the demand for goods and services spurred by the base, account for high employment levels and low number of job seekers in the community (Statistics Canada 2013f). Pembroke's labour force participation and unemployment employment indicators (61.8% and 7.2%) more closely resemble a larger more diversified economy, and are similar to those of the County (62.6% and 7.8%) and Province (65.5% and 8.3%; Statistics Canada 2013f). Almost 7% of the available labour force in Pembroke is employed in the construction industry. This is slightly higher than the provincial average (Statistics Canada 2013d,e). There are 54 construction firms listed in Pembroke Ontario, and include contractors specialized in excavation, industrial buildings and project management (Yellow Pages 2016c). The 2015 Renfrew County labour market planning report identifies that construction is one of the 5 top industries of growth, and identifies that there are 81 registered heavy construction and civil engineering firms in the county. The report also identifies that the number one industry for job seekers to find employment in is the construction industry, followed by retail and customer services/information jobs (Workforce Planning Ontario 2015).

5.10.4.2.5 Income

Table 5.10.4-3 presents the selected individual and family incomes by income source in the Municipality of Laurentian Hills, the Town of Deep River, Petawawa CA, Pembroke CA, the County of Renfrew and the Province of Ontario in 2010. Median income, average income, and median family income in both LSA communities were higher than the Pembroke, County of Renfrew and Province of Ontario (Table 5.10.4-3). The Town of Deep River in particular had a median income ($41,949) that was approximately $11,000 above the provincial median income (Statistics Canada 2013a,d); this is most likely due to the number of residents who are employed at CRL, or who are retired and in receipt of a company pension. Similarly, Petawawa's high median income is due to a large portion of the population being employed by the military.

Table 5.10.4-3: Selected Individual and Family Income by Income Source (2010)

	Municipality of Laurentian Hills	Town of Deep River	Petawawa Census Agglomeration	Pembroke Census Agglomeration	County of Renfrew	Province of Ontario
Median Income ($)	33,711	41,949	43,459	29,220	29,814	30,526
Average Income ($)	40,864	48,621	43,758	37,015	37,131	42,264
Employment Income	68.9%	65.1%	81.6%	67.6%	68.4%	74.8%
Investment Income	1.5%	3.1%	1.2%	3.2%	2.9%	4.2%
Retirement Income	13.0%	19.1%	7.2%	11.1%	11.3%	7.0%

Table 5.10.4-3: Selected Individual and Family Income by Income Source (2010)

	Municipality of Laurentian Hills	Town of Deep River	Petawawa Census Agglomeration	Pembroke Census Agglomeration	County of Renfrew	Province of Ontario
Government Transfer Payments	15.6%	11.1%	9.0%	16.7%	16.1%	12.3%
Median Family Income ($)	78,030	93,429	82,8222	72,240	73,016	80,987

Source: Statistics Canada 2013a,b,c,d,e,f.

5.10.4.2.6 Economic Development

Future economic growth and development opportunities are a key concern for the communities in the region. For instance, the Town of Deep River has identified that they are concerned with the changing demographics (fewer young people and families and a growing senior population) and the perceived difficulty in retaining young people and young families within the community (Jp2g Consultants 2015a). A Strengths-Weaknesses-Opportunities-Threats (SWOT) analysis completed for the Town of Deep River also identified a need to diversify the local economy to reduce dependence on a single employer (Jp2g Consultants 2015a).

Deep River's Strategic Plan aims to promote economic development and in-migration of newcomers to the community through attracting business and people to the community (Deep River 2015). The Town of Deep River has established an Economic Development Advisory Community and aim to have an annual economic development forum to bring local business leaders together to attract investment and retain business. In addition, Deep River will revise its Official Plan to identify new employment lands, set appropriate targets to increase ratio of jobs per population and establish growth plan targets for the community.

The town has developed a population growth target that would see approximately 10% more employees from CNL and CFB Petawawa living in Deep River by 2036 through employment growth and attracting a higher proportion of existing employees (Jp2g Consultants 2015a). Three strategies for economic development that have been proposed in Deep River are using the community's natural assets to promote sustainable tourism, diversifying the housing stock, and developing long-term care services for the elderly (Jp2g Consultants 2015b, Jp2g Consultants 2016).

Similarly, the Municipality of Laurentian Hills are also pursuing economic development opportunities to encourage positive population growth rates than can be achieved by "a significant change in the economic circumstances of the Municipality leading to in-migration" (Laurentian Hills 2010). The municipality has established the Chalk River Business Park where approximately 9.7 ha of land is available for new business and industrial development.

In Petawawa, the military is still driving investment and growth in the economy. The community has, however, identified a need to diversify its economy and attract non-military driven economic development opportunities and have zoned land for industrial and commercial developments (Petawawa 2016b). In 2015, the Government of Canada committed $20 million dollars as investment for CFB Petawawa to improve infrastructure, including roads and military housing at the Petawawa base, and to help create local jobs in the community of Petawawa (Government of Canada 2015).

The largest sectors operating in Pembroke include health care, retail and manufacturing (including wood product manufacturing). The community is also actively encouraging the growth of new business opportunities and has established an economic development strategy and advisory committee that aims to expand and retain industrial and small business ventures. Several parcels of land have been slated for commercial opportunities, including two business parks (Pembroke 2016b).

5.10.4.2.7 Government Finances

Tax revenues reflect the economic vitality of a community, in terms of business activity, local incomes and property values. Tax expenditures help identify key areas of public service and community need. Recent municipal revenues and expenditures in the LSA are presented in Table 5.10.4-4. The NSDF Project will be located on land owned by AECL, a federal Crown corporation. As the land is Crown property, the company makes payments in lieu of taxes to local governments (Government of Canada 2016b). Top revenue sources for the communities in the LSA include municipal and property taxation and user charges. Top expenditures were most often related to protection services, and environmental services (Table 5.10.4-4).

Table 5.10.4-4: Government Expenditures and Revenues in the Local Study Area (Years)

Community (Year)	Total Expenditures ($)	Top Expenditure ($)	Total Revenue ($)	Top Revenue Source ($)	End of Year Financial Position[a,b] (S)
Town of Deep River (2013)	10,389,500	Protection Services, Environmental Services, Recreation and Cultural Services	9,343,330	Taxation, user charges, government transfers	Annual Deficit = (1,046,170), Accumulated Surplus = 21,945,004
Municipality of Laurentian Hills (2014)	3,663,244	Environmental Services, Transportation Services, Protection Services	4,340,609	Property taxes, governments transfers, sewer and water service charges	Annual Surplus = 677,365 Accumulated Surplus = 10,036,152
Municipality of Petawawa (2014)	18,133,789	Environmental Services, Recreation and Cultural Services, Protection Services	20,533,756	User charges, payments in lieu of taxes, Property taxation, Gas Tax Funding	Annual Surplus = 2,399,967 Accumulated Surplus = 84,701,438
City of Pembroke (2013)	33,825,939	Protection Services, Environmental Services, Transportation Services, Recreational Services	35,456,823	Taxation and Payments in Lieu, User Charges, Government Transfers	Annual Surplus = 1,630,884 Accumulated Surplus = 102,919,067

Source: The Corporation of the Town of Deep River 2014; Laurentian Hills 2015.

a) Annual Surplus/Deficit is the difference between Annual Revenue and Expenditures for a given financial year.

b) Accumulated Surplus/Accumulated Deficit refers to the municipalities overall financial position at the end of the fiscal year.

5.10.4.2.8 Housing and Accommodations

In the Town of Deep River, there is a relative shortage of medium to high density housing, with single detached homes comprising the majority of housing in the town (County of Renfrew 2012; Jp2g Consultants 2015a). The town has identified a need for more varied and smaller housing forms. In 2011, of the 1,949 total private dwellings, 76% were single-detached houses, 10% were semi-detached houses, and 13% were units in apartment buildings (Town of Deep River 2015). The town strategized that broadening the types of tenure and housing available to residents will make the community more attractive to live in. The vacancy rate, as reported by local real estate agents, is reported to be very close to zero (Town of Deep River 2015).

Similarly, the majority of housing in the Municipality of Laurentian Hills is also single-detached homes. In 2011, 92% of the 1,190 private dwellings in the municipality were single-detached homes (Town of Deep River 2015). Other housing available in the town are 5 semi-detached houses, 10 row houses, 50 mobile homes and 20 units in an apartment building.

Approximately 70% of the 6,035 houses in Petawawa are single-detached homes. The remaining homes include semi-detached houses (6.3%), row houses (13.3%) and low rise apartment buildings (9.7%) (Statistics Canada 2012d). In Pembroke, 71.6% of the almost 10,000 housing units in the community are single detached houses. Low story apartment buildings account for about 19.4% of all available stock, with the rest being made up of semi-detached and row houses (Statistics Canada 2012e).

Hotel accommodations are available in the Town of Deep River. There is one hotel and five motels in the Town of Deep River, and there are no hotels in the Municipality of Laurentian Hills (Laurentian Hills 2016b). Seven motels are available for temporary accommodation in Petawawa (Hotel Guides 2016). In the City of Pembroke, and the surrounding area, there are approximately 36 temporary accommodations available (Expedia 2016).

5.10.4.2.9 Services and Infrastructure

Traffic and Transportation

The major arterial Highway that connects the NSDF Project to the LSA communities and other regions of Ontario is Highway 17. Highway 17 is the longest highway in Ontario, spanning 1,964 kilometers in a southeasterly direction from Kenora to Arnprior, Ontario. In 2010, Annual Average Daily Traffic counts found that traffic levels between the Village of Chalk River and Deep River ranged from 6,700 and 8,150 vehicles per day (MTO 2010). Traffic volume increases further south along highway 17 around Petawawa and Pembroke and ranged from 7,100 to 9,800 vehicles per day (MTO 2010). Traffic volumes continue to increase beyond Pembroke towards Ottawa.

Waste and Water Management

Chalk River Laboratories has solid waste and waste water facilities on-site that are able to process uncontaminated, contaminated and radioactive waste. On-site waste facilities include landfills for solid waste, such as office garbage and/or waste rock or fill from construction and operation activities. Chalk River Laboratories also has on-site composting facilities for food waste. The capacity of these facilities are projected to be sufficient to capture domestic waste generated from the NSDF Project. Chalk River Laboratories has on-site wastewater facilities including a septic system and a sewage treatment plant. The NSDF Project facilities also include the development of a waste water treatment plant (WWTP), which will be dedicated to servicing the NSDF Project.

Emergency and Protective Services

Fire Services

Chalk River Laboratories has its own fire services that are well staffed and equipped, with 36 full-time firefighters, 4 casual firefighters a 12 member Emergency Response Group, two pumpers, an aerial, and a tanker (Klukas 2016, pers. comm.). Chalk River Laboratories has a minimum of seven firefighters on duty at any given time and respond to site emergencies within four minutes, depending on the location across the site (Klukas 2016, pers. comm.). Chalk River Laboratories has established mutual aid agreements with fire services in the communities nearest to the NSDF Project site, including the Municipality of Laurentian Hills, which provide additional resources upon request if they are not committed to an emergency in their own municipality (Klukas 2016, pers. comm.).

In the LSA, the Town of Deep River and the Municipality of Laurentian Hills have their own fire departments, with the Municipality of Laurentian Hills relying solely upon volunteer firefighters. No capacity issues such as staffing, equipment or training have been identified in the LSA (Beauchamp 2016, pers. comm.; Waito 2016, pers. comm.; Dillon Consulting 2013).

In the RSA, the Municipality of Petawawa has a fire department that has two stations serving the community (Petawawa 2016c). The City of Pembroke also has a fire department that currently has one station, and the department is currently in the process of identifying the location for an additional station to reduce emergency response times (Pembroke 2016c, d).

Emergency Medical Services

Chalk River Laboratories does not have its own emergency medical services. The County of Renfrew Paramedic Services provides paramedic assistance to communities within the County of Renfrew. Every request for paramedic assistance dispatched through the 9-1-1 system or the Community Paramedic Referral Program is responded to by a qualified Paramedic. Of the two LSA communities, only Deep River has an ambulance base. In the RSA, there are ambulance bases in both Petawawa and Pembroke (County of Renfrew 2016b).

In 2016, the County had 133 front-line paramedics, 67 of those were full-time and 66 are part-time paramedics. There are 47 advanced care paramedics and 86 primary care paramedics (Stencil 2016, pers. comm.). The County has a total fleet of 25 Ambulances. Seven ambulance vehicles provide 24 hour coverage seven days a week and 10 ambulances provide 12 hour coverage 7 nights per week throughout the county. There is one emergency response vehicle that operates 24 hours per day, 7 days a week and 5 community paramedic response units, operating 12 hours a day, 7 days a week (Stencil 2016, pers. comm.). The average response time for the Renfrew County emergency medical services is approximately 9 mins (Stencil 2016, pers. comm.).

County representatives note that some of the challenges that they face is that that they serve a large rural county with long distances between communities. There is currently no service agreement in place between the County of Renfrew's emergency medical services and CRL. The County notes that it would be good to have improved interagency operability between different jurisdictions to improve emergency medical services capabilities (Stencil 2016, pers. comm.). The nearest hospital to the CRL property is the Deep River and District Hospital located in Deep River. The Deep River and District Hospital offers emergency care, acute inpatient care, diagnostic imagery, laboratory service and physiotherapy (Deep River and District Hospital 2011a). There are sixteen beds within the hospital and one emergency care physician is on-call or on-site (Deep River and District Hospital 2011b,c). The nearest full-service hospital to the NSDF Project site is the

Pembroke Regional Hospital, located south of Chalk River in the Municipality of Pembroke (Pembroke Regional Hospital 2016).

Protective Services

Chalk River Laboratories has a security service which provides site access control and conventional security to the CRL property. The Deep River Police Service provides policing services to CRL for any criminal charges and/or motor vehicle accidents that happen on site. The Ontario Provincial Police are responsible for policing the Municipality of Laurentian Hills (Town of Laurentian Hill and Village of Chalk River). The OPP also patrols Highway 17.

5.10.4.2.10 Quality of Life

This section presents a description of the existing conditions relating to quality of life for residents living within the LSA. For the purposes of environmental assessment, quality of life is assessed as changes in air quality, ambient noise, increases in traffic volume, and visual disturbances (nuisance effects).

Baseline air quality conditions in the air emissions LSA are described in Section 5.2.1 (Air Quality). The primary source of SO_2 and NO_x in the region is the combustion of fossil fuels, including from the operation of stationary sources, as well as from mobile sources such as vehicles and other equipment. Between 2009 and 2013, no exceedances of the 1-hour or 24-hour Ambient Air Quality Objectives (AAQO) for SO_2 and NO_2 were recorded at the Ottawa Downtown monitoring station[5]. Levels of 24-hour $PM_{2.5}$, particulate matter that can affect air quality for humans by aggravating existing lung or heart conditions, have not been exceeded at the Petawawa or Ottawa Station.

Existing traffic volumes are described in Infrastructure and Services (Section 5.10.4.2.9). In 2013, there were 106,302 motor vehicles registered in the County of Renfrew. The majority of accidents occurred on Highway 17, with 505 total collisions (MTO 2014). Within the county, there were higher numbers of total collisions in the more populated urban communities, with the Municipality of Petawawa having 116 collisions and City of Pembroke registering 161 collisions in 2013. The LSA communities had notably lower number of total collisions, with two collisions occurring in the Municipality of Laurentian Hills and 15 collisions in the Town of Deep River in 2013 (MTO 2014).

Baseline data on existing ambient noise were not collected as the NSDF Project will be constructed on CNL's existing CRL property, located 7 km away from the nearest community, the Village of Chalk River. A visual assessment was not conducted as the NSDF Project will be constructed on CNL's existing CRL property, located 7 km away from the nearest community, the Village of Chalk River. No base case visual information was collected for the NSDF Project.

5.10.4.2.11 Public Safety

The NSDF Project will be located entirely on the CRL property. The NSDF Project site security will follow the CRL security requirements and physical security plans. Access to the NSDF Project site is exclusively from within the CRL property boundary and access to the CRL property is strictly controlled by security personnel. Section 3.5.4.2 more fully describes access control and security management plan for the NSDF Project.

---

[5] NO_2 and SO_2 monitoring was not available at the Petawawa station.

5.10.5 Project Interactions and Mitigation

5.10.5.1 Methods

This section describes the process by which interactions between NSDF Project components and activities and socio-economic VCs were identified and evaluated. Potential effect pathways are identified and mitigation developed to eliminate and/or reduce effects is presented. A pathways analysis is then used to focus the assessment on key interactions between the NSDF Project and the environment by evaluating the different effect pathways to determine if, after incorporation of mitigation, there is still potential to cause residual effects. Where effects will be adequately mitigated and are not forwarded for further analysis (i.e., secondary pathways, or where mitigation will remove the pathway altogether), the reasons for concluding the assessment at this stage are articulated. Primary pathways that may lead to residual effects after incorporation of mitigation are further characterized in subsequent subsections of the assessment. As such, this section helps to focus the remainder of the assessment on those interactions (effects pathways) likely to result in residual adverse effects.

The first part of the analysis was to identify the potential effects pathways for all stages of the NSDF Project. The next step in the analysis was the development of environmental design features and mitigation practices that could be incorporated into the NSDF Project to eliminate and/or reduce effects to socio-economic VCs. Environmental design features included design elements, environmental best practices, and management policies and procedures. Environmental design features and mitigation were developed through an iterative process between the engineering and environmental teams, combined with input from project-specific or regional engagement with other interested parties. The design features and/or mitigation activities were selected considering their effectiveness for implementation and maintenance, and their appropriateness within the context of the identified effect pathways.

After incorporation of mitigation, potential pathways were evaluated into the following categories using scientific knowledge, logic, experience with similar developments, and the effectiveness of environmental design features and mitigation.

- **No pathway –** pathway is removed by environmental design features or mitigation such that the NSDF Project would not be expected to result in a measurable environmental change to measurement indicators identified for socio-economic VCs relative to Base Case values, and therefore would have no residual effects to socio-economic VCs.
- **Secondary pathway –** the pathway could result in a measurable minor change to measurement indicators identified for socio-economic VCs, but would have a negligible residual effect on socio-economic VCs relative to Base Case values and is not expected to contribute cumulatively to other NSDF Project effects or to the effects of other past, present or reasonably foreseeable developments to cause a significant effect.
- **Primary pathway –** the pathway is likely to result in an environmental change to measurement indicators identified for socio-economic VCs relative to the Base Case that could contribute to residual effects to socio-economic VCs.

Environmental design features and mitigation that have been or could be incorporated into the NSDF Project to eliminate and/or reduce adverse effects to socio-economic VCs were considered. Potential pathways that were completely removed due to implementation of environmental design or mitigation were not assessed further. Pathways that were assessed to be secondary and demonstrated to have a negligible residual effect to socio-economic VCs through simple qualitative or semi-quantitative evaluation of the pathway were also not advanced for further assessment. Primary pathways were carried forward for more detailed quantitative and qualitative effects analysis to characterize the residual effects of the NSDF Project on socio-economic VCs (see Section 5.10.6).

5.10.5.2 Results

The results of the pathways analysis is summarized in Table 5.10.5-1. Environmental design features and management policies implemented to reduce potential effects are also described.

Table 5.10.5-1: Pathways Analysis for Socio-economic Valued Components

Project Activity	Valued Component	Effects Pathways	Project Design Features and Policies	Pathway Assessment
Employment of personnel, procurement of goods and services, and expenditures from the NSDF Project	Labour Force	Direct and indirect employment requirements may affect employment and income with the local and regional study areas	Canadian Nuclear Laboratories employment opportunities that may arise due to project activities will be posted on the www.cnl.ca website.	Primary Pathway
	Economic Development	The NSDF Project may provide contracting and supplier opportunities to local and regional businesses	Canadian Nuclear Laboratories will competitively procure material and services for the NSDF Project.	Primary Pathway
	Government Finances	The NSDF Project may contribute to government finances through the payment of property taxes	Payment of taxes	No Linkage
Employment of personnel, use of services and infrastructure for NSDF Project	Housing and Accommodations	The NSDF Project could increase pressure on commercial accommodations	None	Primary Pathway
		Changes in housing demand with respect to LSA housing supply and capacity to meet demand	The construction workforce will be housed in hotels in the Town of Deep River, Municipality of Petawawa and City of Pembroke	No Linkage
	Services and Infrastructure	Changes in demand for community services (health, education, protective and emergency services) with respect to the capacity of LSA services to meet the demand	Continued implementation and maintenance of compliance with all applicable health and safety standards and CNL's existing environmental, safety and security programs	Primary Pathway
		Changes in demand for community infrastructure (e.g., domestic waste management) with respect to capacity of infrastructure to meet demand	Use of existing waste management infrastructure and facilities on the CRL property	No Linkage
		The NSDF Project could increase road degradation due to increased traffic volume from the transportation of workers, supplies, and equipment	Coordinate the transportation of construction equipment and construction materials to site with peak employee traffic times and other periods of high traffic volume on Plant Road and Highway 17 to reduce traffic volumes.	Primary Pathway

Table 5.10.5-1: Pathways Analysis for Socio-economic Valued Components

Project Activity	Valued Component	Effects Pathways	Project Design Features and Policies	Pathway Assessment
Employment of personnel, use of services and infrastructure for NSDF Project (continued)	Quality of Life	The NSDF Project could affect air quality through the generation of emissions and fugitive dust	■ Implementation of Canadian Nuclear Laboratories' Procedure for Management and Monitoring of Emissions, which includes operational control monitoring and verification monitoring. ■ Development and implementation of the Dust Management Plan developed for the NSDF Project, which includes appropriate management techniques to control dust generated by the NSDF Project.	Secondary Pathway
		The NSDF Project could have a negative effect on visual aesthetics and increase noise levels	■ The visual impact of the NSDF Project site will be limited as the line of sight will be obscured by hilly topography and the surrounding tree line. ■ Noise transmission will be mitigated by the topography as the NSDF Project site is situated on the lower side of the hill between Foundation Road and Emergency Route #3.	Secondary
	Public Safety	Public's potential exposure to physical hazards associated with the NSDF Project	Coordinate the transportation of construction equipment and construction materials to site with peak employee traffic times and other periods of high traffic volume on Plant Road and Highway 17 to reduce traffic volumes and potential for traffic accidents.	No Linkage

5.10.5.2.1 No Linkage Pathways

An interaction may have no linkage to environmental effects if the activity does not occur, or if the interaction is removed by mitigation so that the NSDF Project results in no detectable change in measurement endpoints, and subsequently, no residual effect to socio-economic VCs. The following pathways are anticipated to have no linkage to residual effects to socio-economic VCs, and will not be carried through the residual effects assessment in Section 5.10.6.

- **The NSDF Project may contribute to government finances through the payment of property taxes.**

As the NSDF Project will be built on CNL's existing CRL property, which is located on federal land, no additional property taxes are required. Payment in lieu of taxes will continue to be paid to the Town of Deep River. This potential project-environment interaction has therefore been assessed as having no change from existing conditions.

- **Changes in demand for community infrastructure (e.g., domestic waste management) with respect to capacity of infrastructure to meet demand.**

All wastes that arise as a result of the construction, operations, and closure phases will be safely managed and in accordance with CNL's Waste Management Program. The CNL Waste Management Program prescribes that management of solid waste at CNL-operated sites is completed in a safe and environmentally responsible manner that meets or exceeds applicable regulations and standards, and limits current and future environmental effects and liabilities. Facilities and activities within these sites are planned, developed and operated or conducted in a manner that reduces both the volume and the level of hazard of all wastes that are generated during the entire life cycle of the facility or activity. Under the Waste Management Program, wastes are managed in accordance with CNL's Management of Solid Waste and Management of Liquid Waste documents, and CNL's Waste Generation and Handling Standards.

Conventional waste generated during construction and operations will comprise consumables and sanitary waste. Conventional (non-radiological) waste generated from the NSDF Project during construction and operations will be managed at CRL's Inactive Landfill, located to the east of the NSDF Project site (Figure 1.0-1). Types of consumables include non-reusable/recyclable construction materials, and other regular waste generated at an industrial work site. Each contractor on-site will be responsible for their own housekeeping and waste handling/disposal. Standard mitigation measures will be implemented for storage of conventional waste at the site, prior to disposal at the landfill (e.g., collection and storage in appropriate wildlife-resistant containers). Construction materials will be re-used or recycled, if possible.

Hazardous (non-radiological) materials generated during construction and operations will be typical of those generated for construction of large industrial facilities and will include solvents, chemicals, cleaners, aerosol cans, compressed gases, oils and lubricants. These materials will be managed, including storage, use and disposal, in compliance with applicable legislation, codes and CNL's Waste Generation and Handling Standards. Once collected by a licensed hazardous waste disposal company, these wastes will be transferred off-site to licensed waste management facilities for treatment and/or disposal.

During site preparation and construction, waste management includes managing conventional wastes that are generated as part of the work activities. No radioactive waste is expected to be generated during site preparation and construction activities. In the unlikely event any material is found to be contaminated with radioactive material, it will be separated and managed according to existing procedures established for all CNL operated sites, which are consistent with applicable regulations.

Chalk River Laboratories' Sewage Treatment Plant receives approximately 700 cubic metres (m^3) of grey water/sewage per day. Approximately 3,150 staff work on the CRL property. A peak workforce of 50 staff will be required for the NSDF Project (see Section 3.12) and grey water/sewage generation rates are similar to the CRL property. The grey water/sewage will be stored in a holding tank at the NSDF Project site and periodically transferred to the CRL Sewage Treatment Plant.

The NSDF Project is not expected to require the use of waste management facilities in the nearby communities of Deep River and Chalk River as there are existing infrastructure and facilities available on CNL's existing CRL property. This potential project-environment interaction has therefore been assessed as having no linkage to residual effects to local services and infrastructure.

- **Public's potential exposure to physical hazards associated with the NSDF Project.**

The NSDF Project site security will follow CRL's site security requirements and physical security plans (see Section 3.5.4.2). Access to the NSDF Project site is exclusively from within the CRL property boundary and access to the CRL property is strictly controlled by security personnel. In addition, a security fence will be installed around the entire perimeter of the ECM to prohibit unauthorized personal from entering, and to limit animal injury and contact during construction and waste placement operations. Section 3.5.4.2 more fully describes access control and security management plans for the NSDF Project. As security measures will be put in place to limit access to the NSDF, this potential project-environment interaction has therefore been assessed as having no linkage to residual effects to quality of life for local residents.

- **NSDF Project-related in-migration could increase demand for housing.**

Residential housing in the LSA is not expected to be affected by the temporary presence of NSDF Project construction workers. NSDF Project employment during the construction phase will be temporary in nature, and filled largely by contractors from the LSA and RSA, although some may also be out of area. Temporary workers from outside of the LSA will be housed in commercial accommodations and are not expected to relocate permanently to the LSA due to the temporary nature of employment. Given that no project in-migration is expected and workers will be housed in commercial accommodations (i.e., hotels), an increased demand for housing is not expected. As such, this potential project-environment interaction has therefore been assessed as having no linkage to residual effects to local housing and accommodations.

5.10.5.2.2 Secondary Pathways

In some cases, an interaction may exist, but since the change caused by the NSDF Project is anticipated to be negligible, it has no measureable or detectable effect on socio-economic VCs relative to baseline conditions. The following pathway is expected to be secondary and will not be carried through the residual effects assessment in Section 5.10.6.

- **The NSDF Project could affect air quality through the generation of emissions and fugitive dust.**

The Procedure for Management and Monitoring of Emissions for CNL outlines the key management practices that limit air quality emissions effects, as well as the current monitoring requirements. In addition, development and implementation of the Dust Management Plan developed for the NSDF Project, which includes appropriate management techniques to control dust generated by the NSDF Project, will also reduce the generation of emissions and fugitive dust.

General dust control measures during construction and operation include water spray applied to unpaved roads, excavation areas, and work areas as needed to control dust. Water will be used as the primary dust control measure for construction and operation activities. When water cannot be used during winter periods or it is not the preferred method for temporary or longer term dust control, fixatives (e.g., chemical suppressant) will be used in accordance with the Dust Management Plan to be developed for the NSDF project. The NSDF dust management procedure will address specific protocols for water or chemical application for dust control during construction and operational periods. Vehicle and equipment traffic on the site will be controlled and limited to avoid contact with waste and cover materials, and speed limits are placed on all access roads. Material handling and excavation activities are limited to designated areas to limit handling of materials and prevent the generation of dust wherever possible

Predicted concentrations of air emissions and fugitive dust for the Application Case during both construction and operations phases are below applicable air quality guidelines and/or standards. Consequently, this potential project-environment interaction considered to have a negligible residual effect on quality of life.

- **The NSDF Project could have a negative effect on visual aesthetics and increase noise levels.**

The visual impact of the NSDF Project site will be limited as the line of sight will be obscured by hilly topography and the surrounding tree line. The NSDF Project is not expected to be visible to the local public. Noise transmission will be mitigated by the topography as the NSDF Project site is situated on the lower side of the hill between Foundation Road and East Mattawa Road. Changes in ambient noise levels are not expected to be detected in the LSA communities due to the distance from the NSDF Project site (i.e., Village of Chalk River is the nearest local community and is located 7 km west of the CRL property).

Noise-level changes often considered in an environmental assessment include noise-induced sleep disturbance, noise complaints, long-term high annoyance. For the NSDF Project, a qualitative assessment of the acoustic environment was carried out based on the separation distance between the NSDF site and the nearest sensitive locations. In accordance with MOECC guideline NPC 300 (MOECC 2013), sensitive locations include permanent and/or seasonal dwellings. Communities in the vicinity of the NSDF site are shown on Figure 5.10.3-1, which includes the nearest cottages on the Quebec side of the Ottawa River, approximately 4 km from the NSDF site. Based on this separation distance, a detailed assessment is not typically required by the MOECC. In addition, based on the Health Canada guidance (Health Canada 2016), a less extensive

assessment may be warranted if noise levels at all receptors are not expected to result in a change in%HA exceeding 6.5%.

The haulage route for transportation of site preparation and construction equipment, and construction materials will be via public roads to the CRL property (e.g., Highway 17). It is estimated that there will be 14 trucks per day during construction and 10 trucks per day during operations. This results in less than 2 trucks per hour during construction and less than 1 truck per hour during operations for the daytime period. In addition, it is assumed that construction workers will travel to the NSDF Project site from the local commercial accommodations using their own personal vehicles (i.e., 50 vehicles). The transport vehicles will pass through the town of Chalk River. This level of activity is not expected to result in a change in%HA greater than 6.5%. Similarly, the noise levels associated with these truck movements are not expected to increase noise levels above 75 dBA (the level at which noise complaints may include strong appeals to authorities to stop noise [Health Canada 2016]) and are not expected to result in noise-induced sleep disturbance. Noise transmission will be mitigated by the topography as the NSDF Project site is situated on the lower side of the hill between Foundation Road and Emergency Route #3.

Overall, the increase in transport vehicles is considered negligible in comparison to current traffic levels on the road (personal vehicle traffic for over 2000 employees and transport vehicles) to support operation of the CRL site. The effect of increased traffic on noise levels is considered to be a slight but discernible change when compared to existing levels of traffic from current employees and operations at CRL. Transportation of site preparation and construction equipment, and construction materials will be scheduled to reduce noise and traffic volumes, and limit inconvenience to local residents. As such, this potential project-environment interaction considered to have a negligible residual effect on quality of life.

5.10.5.2.3 Primary Pathways

The following primary pathways were identified as having a residual effect on socio-economic VCs and have been carried forward to the residual effects analysis:

- direct and indirect employment requirements may affect employment and income with the local and regional study areas;
- the NSDF Project may provide contracting and supplier opportunities to local and regional businesses;
- the NSDF Project could increase pressure on commercial accommodations;
- changes in demand for community services (health, education, protective and emergency services) with respect to the capacity of LSA services to meet the demand; and
- the NSDF Project could increase road degradation due to increased traffic volume from the transportation of workers, supplies, and equipment.

5.10.6 Residual Effects Analysis

5.10.6.1 Methods

This section builds on the environmental assessment approach outlined in Section 5.1 and will describe the specific methods used to predict changes to socio-economic VCs and assess the residual effects. Residual effects will be evaluated for the Application Case and RFD Case. Only primary pathways identified in Section 5.10.5 Project Interactions and Mitigation are included in the residual effects analysis.

5.10.6.2 Application Case Results

This section describes the residual effects of the NSDF Project on the socio-economic VCs for primary pathways (Table 5.10.5-1). The section also describes the appropriate mitigations for each effect and characterizes the residual effect from the NSDF Project after mitigations have been applied.

5.10.6.2.1 Labour Market and Economic Development

The NSDF Project is expected to be constructed between July 2018 and March 2020. The key surface structures that will be constructed for the NSDF Project are the engineered containment mound (ECM), wastewater treatment plant (WWTP), access roads, and support facilities and infrastructure. The construction phase will require an average of 45 full-time equivalents, with a peak workforce of approximately 50 full-time equivalents. The labour force is expected to be variable depending on the number of parallel activities being performed. Limited maintenance and inspection will occur in off-shift hours. Operations, closure and post-closure labour force requirements are expected to be less than requirements for the construction phase. Given the nature of the NSDF Project construction activities, it is expected that the construction workforce will be sourced from firms within the LSA, RSA (throughout the County of Renfrew), and the Ottawa area. Canadian Nuclear Laboratories employment opportunities that may arise due to NSDF Project activities will be posted on the www.cnl.ca website.

The industries that will supply the NSDF Project with goods and services (e.g., manufacturing, wholesale, transport), are anticipated to be concentrated in the RSA (County of Renfrew) and the Ottawa area. The construction workforce will, therefore, either already live in the RSA or may come from out of area and require temporary residence in the Town of Deep River, the Municipality of Petawawa and the City of Pembroke. The potential exists for a modest increase of expensed meals and accommodations due to the construction workforce who may seek to temporarily reside in the LSA and RSA during the construction phase.

5.10.6.2.2 Service and Infrastructure

Transportation and Traffic

The haulage route for transportation of site preparation and construction equipment, and construction materials will be via public roads to the CRL property (e.g., Highway 17) and will be scheduled to reduce noise and traffic volumes, and limit inconvenience to local residents. Construction materials (e.g., processed granular materials and gravel, geosynthetic products and clay) will be transported to the NSDF Project site using standard highway haul vehicles. It is estimated that during site preparation and construction, 115 truckloads of material will be delivered per day. In addition, it is assumed that construction workers will travel to the NSDF Project site from the local commercial accommodations using their own personal vehicles (i.e., 50 vehicles). Within the CRL property, transport of site preparation and construction equipment, and construction materials to the NSDF Project site will be by the Plant Road, which leads to the main site access road. This increase in traffic from the transportation of workers, supplies and equipment for the NSDF Project is expected to result in degradation of public transportation infrastructure.

Emergency and Protective Services

Emergency and protective services at CRL rely on CRL's own internal capacity as the first responder to incidents at the NSDF Project site. For more serious incidents, CRL may rely on the County of Renfrew and the Town of Deep River, respectively. As there are no mutual aid agreements for these services, the NSDF Project may potentially increase demand for emergency and protective services in neighbouring municipalities or in the County due to the need to respond to project-related incidents.

During all phases of the NSDF Project, several strategies will be in place to reduce the likelihood of an incident occurring and to avoid the requirement for community emergency services. Additional mitigation includes operating in compliance with all applicable federal and provincial health and safety standards and CNL's existing Environmental, Safety and Security programs (see Section 3.13.2).

5.10.6.2.3 Housing and Accommodations

It is anticipated that the out-of-area construction workforce will be housed in hotels in the Town of Deep River, Municipality of Petawawa and City of Pembroke. As a portion of the construction workforce is expected to be sourced from the LSA, RSA and County of Renfrew it is not expected to substantially increase the demand on commercial accommodations (i.e., hotels) during the construction phase of the Project.

5.10.6.3 Reasonably Foreseeable Development Case Results

This section describes the residual effects of the NSDF Project on the socio-economic VCs in consideration of other reasonably foreseeable developments that may overlap spatially and temporally with the NSDF Project. The CNL NPD Project is the only foreseeable project that has been identified to overlap spatially and temporally with the NSDF Project. The NPD Project is a decommissioning project with relatively small employment and procurement levels (i.e., 15 to 30 external contractors and $5 to $10 million in expenditure). The following sub-sections describes the predicted cumulative residual effects from the NPD Closure Project and the NSDF Project.

5.10.6.3.1 Labour Market and Economic Development

Canadian Nuclear Laboratories' NPD Project is expected to be executed over a two year period from 2018 to 2020. It will employ approximately 50 people (20 of the 50 workers will be existing CNL employees), with 15 to 30 external contractors that will be sourced from the LSA and RSA communities, with a limited number of specialized contractors coming from Ottawa and the Greater Toronto Area. The value of supplier contracts is estimated to be approximately $5 to $10 million dollars.

Given the size of the labour force in the LSA and RSA in 2011 of approximately 24,460 persons, with an unemployment rate of 6.2% (Statistics Canada 2013a,b,e,f), it is not expected that local labour will be constrained in consideration of the demand for labour from both the CNL NSDF and NPD Projects, where peak workforce could potentially be 80 workers in 2018. The economic contribution of direct, indirect and induced project spending is also expected to be small when considering the size of the local economy in the RSA and LSA.

5.10.6.3.2 Services and Infrastructure

Transportation and Traffic

As the NPD Project is a decommissioning project, it is not expected to require a lot of transportation to and from the CNL site. The NPD Project is projected to increase traffic by approximately 20 vehicles per day delivering goods and services to the CNL site. There will also be additional traffic associated with an estimated 30 workers commuting to and from the CRL site each day (i.e., 20 of the 50 workers will be existing CNL employees).

In consideration of the increased traffic from the NSDF Project, and the average annual daily traffic (AADT) levels in the LSA and RSA, which range from 6,700 to 9,800 vehicles per day, the cumulative effects of traffic from the NPD and NSDF projects may slightly increase traffic levels during the morning and evening commutes. This increased traffic may be noticeable in Deep River, the closest community to the NSDF Project site, however the cumulative residual effects of traffic from the NPD and NSDF projects is not likely to be a nuisance to residents in LSA and RSA communities. Canadian Nuclear Laboratories will also aim to schedule the delivery of vehicles travelling to and from site with construction and decommissioning materials at a time that does not interact with high traffic such as the morning and evening commutes.

Emergency and Protective Services

Emergency and protective services at CRL generally rely on CRL's own internal capacity. Chalk River Laboratories' existing emergency and protective services at both the CRL property and the NPD site are expected to be sufficient for the NSDF and NPD project activities, respectively. There may be a potential increase in demand for emergency and protective services in the LSA and RSA communities, as well as the County, due to the need to respond to more serious project-related incidents. However, the predicted residual effect is expected to be limited due to the size of the workforces of both projects.

5.10.6.3.3 Housing and Accommodation

The maximum number of workers that may have to be housed in the LSA and RSA for the NPD Project is 30 workers over the period of 2018 to 2020. Similar to the NSDF Project, it is expected that a portion of the NPD Project's workforce would come from the LSA and RSA and, therefore, already be residents of the area and not require temporary accommodation.

When considered with the NSDF Project temporary accommodation requirements, and the availability of hotels, motels and other accommodation in the LSA and RSA, it is not expected that the combined effects of the NPD and NSDF projects will place considerable constraints on temporary accommodation in LSA and/or RSA communities.

5.10.7 Prediction Confidence and Uncertainty

Predictions of the NSDF Project's effects on socio-economics carry an element of uncertainty because many factors will affect the future, including how individuals' choices will affect their personal and community circumstances. For example, the proportion of workers who live in the local communities may continue to be the same, but it is also possible that more workers will choose to live elsewhere and commute into the area for their work shift. The NSDF Project's effects will also be influenced by economic conditions and broad factors affecting societal change within the communities affected by the NSDF Project.

Confidence in the prediction of the effects of the NSDF Project on the socio-economics of the local communities is based on a number of assumptions of future conditions, including the following:

- workers' skill requirements will be similar to those existing at CRL;
- working conditions (e.g., shift schedules) will be the same;
- most workers at the NSDF Project during the operations phase will be the same individuals currently employed at CRL; and
- employees will continue to live in the same communities.

The confidence in the effects assessment for socio-economics is considered to be moderate. A key source of uncertainty in the assessment is related to the Base Case and the contribution to residual effects from the Garrison Petawawa Canadian Armed Forces expansion. Although activities related to the expansion are expected to be completed by 2017; the economic benefits from these activities will continue well beyond the completion of the work. Because the activities have not yet completed, there is uncertainty in the contribution of these effects to the Base Case, and subsequently, the combined effects for the Application Case. However, it is expected that effects from these activities will largely be positive; therefore, residual effects predicted for the Application Case are considered to be conservative.

Mitigation proposed in the assessment is based on accepted and proven best management practices that are well-understood and have been applied to numerous nuclear waste containment construction projects throughout Canada. Uncertainty in the assessment has been reduced by making conservative assumptions, planned implementation of known effective mitigation and monitoring, and available adaptive management measures to address unforeseen circumstances should they arise.

Certainty of the predicted effects for commercial accommodation is high, given the effectiveness of the mitigation to be implemented and knowledge of the NSDF Project design and schedule. However, events that may require emergency and protective services are difficult to predict. Mitigation regarding best practices and emergency response are reliably effective and have been or are currently being used pursuant to the *Nuclear Safety and Control Act* and CNL's existing Environmental, Safety and Security Programs (see Section 3.13).

5.10.8 Residual Effects Classification and Determination of Significance

This section classifies the residual effects from cumulative changes to measurement indicators for the Application Case and presents a determination of significance for each socio-economic VC that was predicted to be affected by a primary pathway. Although the positive and neutral residual effects associated with the NSDF Project are reported in this section, they are not assessed for significance.

5.10.8.1 Residual Effects Classification

Effects from adverse residual changes to measurement indicators were classified using a categorical scale and common words to facilitate the determination of significance. The purpose of categorical classification is to provide definitions that permit a clear, thorough and unambiguous classification of residual effects such that reviewers and readers can follow and apply the logic used in the assessment and reach the same classification for a given residual effect.

All primary pathways affecting each measurement indicator were combined for the residual effects classification such that one classification is provided for each measurement indicator. Changes to measurement indicators are classified for each VC, for the Application Case. The classification is based on the residual effects analysis provided in Section 5.10.6.

Magnitude, geographic extent and duration are the principal factors considered to predict significance (Table 5.10.8-1). Magnitude refers to the degree of change in the measurement indicator. Magnitude may be low, moderate or high. Economic effects were assigned magnitude qualitatively based on levels of concern, analysis of the existing economic environment and projected future changes as they affect economic sustainability. Geographic extent refers to the area affected and is categorized into three scales: local, regional and beyond regional. Local effects are those confined to the communities in the LSA. Regional effects include the LSA, but do not extend beyond the RSA. Beyond regional refers to effects that extend beyond the region and throughout the province of Ontario or even farther. Duration is defined as the amount of time from the beginning of an effect when the effect on a VC has ended or dissipated to the point of not being detectable and is expressed relative to project phases.

Direction indicates whether an effect is considered negative (i.e., less favourable) or positive (i.e., beneficial). While the focus of the effects assessment is to predict whether the development is likely to cause significant adverse effects on the environment or cause public concern, the positive and neutral changes associated with the Project are reported. Some effects may have both positive and negative dimensions. For example, although increased income from employment can increase spending in local communities, there is also a cost associated with the management of an out of area workforce by municipalities and infrastructure and service providers.

Some of the criteria used to determine significance in other sections of the EIS have limited or no application to the socio-economic assessment, and include the following criteria.

- **Frequency** refers to number of times an effect is expected to occur over a given period. Although there are isolated exceptions, most economic effects are experienced continuously and are cumulative (i.e., they interact and are directed and shaped by the broader continuously evolving economic environment). Thus, frequency generally is not deemed an applicable criterion for the socio-economic assessment.

- **Reversibility** is defined as the probability and time required to return to a state that is similar to baseline or comparable to similar environments not affected by the NSDF Project. Socio-economic effects associated with a project are typically part of an ongoing process of interdependent economic, social and cultural changes extending into the future, which generally cannot be reversed to return to the pre-development conditions. For example, although most employment will come to end at retirement, job experience and training will have enhanced capacity of individuals to find other employment, with lifelong implications (i.e., the employment effect will not be reversed fully).
- **Likelihood** of the predicted NSDF Project effects are all assumed to be high (i.e., occurring) if the NSDF Project proceeds for the purpose of the assessment.

Table 5.10.8-1: Assessment Criteria for Classifying Predicted Residual Adverse Effects to the Socio-economic Valued Components

Direction	Magnitude	Geographic Extent	Duration
Positive: An improvement over Base Case values or conditions **Neutral:** No change to measurement indicators over Base Case values or conditions **Negative:** A less favourable change to measurement indicators relative to Base Case values or conditions	**Negligible:** No discernible change is expected from Base Case values or conditions **Low:** A slight, but discernible change to measurement indicators from Base Case conditions, but within the capacity of the system **Moderate:** The change to measurement indicators is detectable, but still remains within historical system capacity or market capacity for response **High:** The change to measurement indicators are beyond historical norms or existing system or market capacity for effective response	**Local:** The change to the measurement indicator will not extend beyond communities in the Local Study Area (LSA) **Regional:** The change to the measurement indicator will affect the Regional Study Area and LSA (where the changes are more widespread, but still detectable) **Beyond Regional:** The change to measurement indicators will extend beyond the RSA into other areas of the Province	**Short-term:** The change to measurement indicators occurs during construction, but ends before the end of construction; or occurs during active closure stage only, but ends before final closure. **Medium-term:** The change to measurement indicators occurs throughout operations and ends before or near the end of operations. **Long-term:** The change to measurement indicators will extend beyond the operational life of the NSDF Project.

5.10.8.2 Determination of Significance

The classification of primary pathways and the associated predicted changes in measurement indicators provide the foundation for determining the significance of effects from the NSDF Project on the socio-economic VCs. Effect criteria of magnitude, duration and geographical extent are discussed in the context of the changes to the socio-economic measurement indicators from the NSDF Project to the existing environment. As previously mentioned, positive and neutral residual effects associated with the NSDF Project are not assessed for significance.

For socio-economic VCs, an adverse effect was considered significant if it was predicted to have an effect of high magnitude at the local, regional or provincial geographic extent with a long-term duration. When considering a high magnitude rating, an adverse socio-economic effect was considered significant if the effect was predicted to result in the capacity of the system being exceeded on an ongoing and consistent basis and the system is unlikely to be able to respond in a timely manner. As part of the determination of significance, confidence in the assessment identified in Section 5.10.7 was considered for each VC.

5.10.8.2.1 Labour Market and Economic Development

Residual effects from the NSDF Project on the labour market and economic development are predicted to be positive. The effects are predicted to be local, regional and beyond regional as is expected that the construction workforce will be sourced from the LSA, RSA, County of Renfrew and the Ottawa area. The effect is considered medium-term (i.e., during Project construction and operations).

An increase in procurement of goods and services from local and regional contractors and businesses is expected during the NSDF Project construction (i.e., positive effect). Procurement of construction goods and services is expected to be regional due to the lack of suitable construction firms and associated industries in the LSA. The construction workforce is expected to reside temporarily in the Town of Deep River, the Municipality of Petawawa and City of Pembroke; therefore, the increase in meals and accommodations during construction is expected to be low relative to the size of the local economy, local in geographic extent, and short-term in duration (Table 5.10.8-2).

Table 5.10.8-2: Evaluation of Predicted Residual Effects on Labour Market and Economic Development for the Application Case

Indicators	Direction	Magnitude	Geographic Extent	Duration	Significance
Employment opportunities and income generation	Positive	Low	Local to Beyond Regional	Medium-term	Not applicable (significance is not determined for positive effects)

The predicted residual effect of the NSDF Project, in combination with the NPD Project, are not expected to increase constraints on labour; therefore, the magnitude of the cumulative residual effect on employment opportunities is predicted to be low in magnitude, local to beyond regional in geographic extent and medium-term in duration (Table 5.10.8-3).

Table 5.10.8-3: Evaluation of Predicted Residual Effects on Labour Market and Economic Development for the RFD Case

Indicators	Direction	Magnitude	Geographic Extent	Duration	Significance
Employment opportunities and income generation	Positive	Low	Local to Beyond Regional	Medium-term	Not applicable (significance is not determined for positive effects)

5.10.8.2.2 Housing and Accommodations

There may be limited amounts of increased pressure on commercial accommodations during construction of the NSDF Project. The predicted residual effect of construction activities on the availability of commercial accommodations is negative in direction because it has the potential to reduce availability of temporary accommodation during periods of high demand, such as peak tourism periods. Given the available hotel capacity in the Town of Deep River, Municipality of Petawawa and City of Pembroke (one hotel and five motels in Deep River and additional hotels in the Municipality of Petawawa and City of Pembroke) and the peak construction workforce expected (50 at peak), the NSDF Project is expected to have a slight, but discernible effect on commercial accommodation availability (i.e., low magnitude). Overall, the residual effect of the NSDF Project on commercial accommodation availability is determined to be not significant (Table 5.10.8-4).

Table 5.10.8-4: Evaluation of Predicted Residual Effects on Commercial Accommodations for the Application Case

Indicators	Direction	Magnitude	Geographic Extent	Duration	Significance
Increased pressure on commercial accommodations	Negative	Low	Local to Regional	Short-term	Not Significant

The additional 30 employees at the peak employment period for the NPD Project is not expected to place any additional pressure on commercial accommodation availability in the LSA and RSA communities. The cumulative residual effect on commercial accommodation availability from the NPD Project and NSDF Project is predicted to be of low magnitude, local to regional in extent, and short-term in duration. Overall, the cumulative residual effect on commercial accommodation availability is predicted to be not significant for the RFD Case (Table 5.10.8-5).

Table 5.10.8-5: Evaluation of Predicted Residual Effects on Commercial Accommodations for the RFD Case

Indicators	Direction	Magnitude	Geographic Extent	Duration	Significance
Increased pressure on commercial accommodations	Negative	Low	Local to Regional	Short-term	Not Significant

5.10.8.2.3 Service and Infrastructure

Transportation and Traffic

Increased road degradation due to increased traffic volume on highways and local roads used to access the NSDF Project is predicted during construction. The predicted residual effect of construction activities on highways and local roads used to access the NSDF Project is negative in direction because the increase of traffic for the NSDF Project will place increased pressure on road infrastructure in the LSA and RSA. It is considered short-term in duration because the measurable increase in traffic volume will occur only during NSDF Project construction. The effect of increased traffic on road conditions is considered to be a slight but discernible change (i.e., low magnitude) when compared to existing levels of traffic from current employees and operations at CRL. The effect is considered beyond regional as traffic is expected to come from outside the RSA on Plant Road and Highway 17. Overall, the NSDF Project's residual effect on transportation and traffic is determined to be not significant (Table 5.10.8-6).

Table 5.10.8-6: Evaluation of Predicted Residual Effects on Transportation and Traffic for the Application Case

Indicators	Direction	Magnitude	Geographic Extent	Duration	Significance
Increased road degradation due to increased traffic volume from the transportation of workers, supplies, and equipment.	Negative	Low	Beyond Regional	Short-term	Not Significant

In consideration of the limited amount of traffic from decommissioning activities at the NPD Project, and the relatively small peak workforce that would be commuting to and from the NPD site for the duration of the NPD Project, the increased levels of traffic are considered to be low in magnitude when considered with the effects of the NSDF Project. Increased traffic from the NPD and NSDF projects are expected to occur beyond regional and short-term in duration. Overall, the cumulative residual effect on transportation and traffic is predicted to be not significant for the RFD Case (Table 5.10.8-7).

Table 5.10.8-7: Evaluation of Predicted Residual Effects on Transportation and Traffic for the RFD Case

Indicators	Direction	Magnitude	Geographic Extent	Duration	Significance
Increased road degradation due to increased traffic volume from the transportation of workers, supplies, and equipment.	Negative	Low	Beyond Regional	Short-term	Not Significant

Emergency Services

The NSDF Project will have a residual effect on the demand for emergency services during construction and operation. The predicted residual effect of the Project on the provision of emergency services is negative in direction because of the potential increased demand on a limited service. The effect is regional in extent because emergency services operate at a regional level in the LSA and RSA. A minor incident could result in personal injury requiring minimal emergency medical care, while a major incident could result in the need for substantial emergency medical care.

While the risk of a major incident is low, and made even less likely by CRL's internal capacity and project-related mitigations, accidents by their very nature are unpredictable, as are their outcomes. The added demand associated with the NSDF Project will not lead to unmanageable service requirements or delivery due to the excess of capacity generally. Therefore, the Project's residual effect on emergency services is assessed to be of negligible to moderate magnitude. Due to the nature of the Project, the predicted residual effect is considered long-term as the risk of Project-related accidents could occur during Project construction, operations, and closure. The Project's residual effect on emergency services is determined to be not significant (Table 5.10.8-8).

The predicted residual effect of construction activities on the provision of protective services is negative in direction because of the potential increased demand on a limited service. As with demand for emergency services, it is not known with any certainty whether or not the Project will bring about increased demand for protective services. Regular, planned construction activities are not expected to place demand on police services in the LSA or RSA. As all workers are expected to abide by CNL's environmental, safety and security policies and programs, the magnitude of this effect on service provision is considered to be negligible as it is expected that the protective services in the LSA would have sufficient capacity to respond to the incident. As this effect will persist only through construction, and would likely be felt in communities where the construction workforce will reside, it is considered short-term and regional in extent as workers may reside outside of the LSA in the Municipality of Petawawa and City of Pembroke. The Project's residual effect on protective services is determined to be not significant (Table 5.10.8-8).

Table 5.10.8-8: Evaluation of Predicted Residual Effects on Emergency Services on the Application Case

Indicators	Direction	Magnitude	Geographic Extent	Duration	Significance
Increased demand for emergency services	Negative	Negligible to Moderate	Regional	Short-term to Long-term	Not Significant
Increased demand for protective services	Negative	Negligible	Regional	Short-term	Not Significant

The demand for emergency services will continue to depend on the occurrence and severity of an accident, which is unplanned by its nature. In consideration of the NPD Project, the demand for emergency services will be negative in direction, negligible to moderate in magnitude and regional in geographic extent. As the decommissioning activities of the NPD Project are for a two-year period, the duration of the cumulative residual effect is predicated to be short-term. The cumulative residual effect on emergency services for the RFD case determined to be not significant (Table 5.10.8-9).

The predicted cumulative residual effect of the RFD case on protective services is assessed to be negative in direction and negligible in magnitude due to the small workforce and implementation of CNL's environmental, safety and security policy and programs. The effect will be regional in geographic extent and short-term in duration, only taking place during the decommissioning phase of the NPD Project and the construction phase of the NSDF Project. The cumulative residual effect on protective services in consideration of the RFD case is determined to be not significant (Table 5.10.8-9).

Table 5.10.8-9: Evaluation of Predicted Residual Effects on Emergency Services on the RFD Case

Indicators	Direction	Magnitude	Geographic Extent	Duration	Significance
Increased demand for emergency services	Negative	Negligible to Moderate	Regional	Short-term	Not Significant
Increased demand for protective services	Negative	Negligible	Regional	Short-term	Not Significant

5.10.9 Monitoring and Follow-up

Monitoring and follow-up programs are not specifically identified for socio-economics; rather, monitoring for environmental pathways noted above (i.e., for air quality, water quality and groundwater quality) will be implemented to verify effects predictions. This monitoring will be on going during construction, operations and closure and the need for and duration of monitoring will be reviewed based annual review of monitoring data. Recognizing people's interest in understanding and participating in decisions that affect them, CNL will proactively seek, engage, and support meaningful discussion on issues and opportunities related to the NSDF Project as part of the Public Information Program. Canadian Nuclear Laboratories' will continually evaluate both the process and the outcome of the ongoing engagement and communication activities to address and manage issues as they arise. The level and nature of engagement with the communities will depend on feedback received.

5.10.10 Conclusions

Valued components refer to environmental features that may be affected by a project and that have been identified to be of concern by the proponent, scientists, government agencies, First Nation and Métis peoples, or the public (The Agency 2014). Socio-economic VCs were selected based on the potential for the NSDF Project to interact with the features of the socio-economic environment, and include:

- Labour Market;
- Economic Development;
- Government Finances;
- Housing and Accommodations;
- Services and Infrastructure;
- Quality of Life; and,
- Public Safety.

Residual effects from activities that occur during the construction phase have been identified as the primary linkage to potentially affect socio-economic VCs. During the construction phase, NSDF Project activities will result in residual effects from direct and indirect employment requirements, contracting and supplier opportunities, increased pressure on commercial accommodations, changes in demand for community services, and increased degradation of public transportation roads. A summary of the predicated residual effects for socio-economics, including associated mitigation, are provide in Table 5.10.10-1. Examples of mitigation practices implemented to limit predicted residual effects to socio-economic VCs include:

- continued implementation and maintenance of compliance with all applicable health and safety standards and CNL's existing environmental, safety and security programs;
- continued implementation of Canadian Nuclear Laboratories' Procedure for Management and Monitoring of Emissions, which includes operational control monitoring and verification monitoring;
- implementation of the Dust Management Plan developed for the NSDF Project, which includes appropriate management techniques to control dust generated by the NSDF Project; and
- coordinate the transportation of construction equipment and construction materials to site with peak employee traffic times other periods of high traffic volume on Highway 17 to reduce traffic volumes.

Recognizing people's interest in understanding and participating in decisions that affect them, CNL will proactively seek, engage, and support meaningful discussion on issues and opportunities related to the NSDF Project as part of the Public Information Program. Canadian Nuclear Laboratories' will continually evaluate both the process and the outcome of the ongoing engagement and communication activities to address and manage issues as they arise.

Table 5.10.10-1: Summary of Predicted Residual Effects for Socio-economics Valued Components

Valued Components	Assessment Endpoint	Residual Effects	Project Phase Residual Effect Occurs	Contributing Project Activity	Proposed Mitigation	Significance	
						Application Case	RFD Case
Labor Market	Continuation of employment opportunities and income generation	Direct and indirect employment requirements may affect employment and income with the local and regional study areas	Construction	Employment of personnel, procurement of goods and services, and expenditures from the NSDF Project	Canadian Nuclear Laboratories employment opportunities that may arise due to project activities will be posted on the www.cnl.ca website.	Positive residual effect therefore, significance is not determined	Positive residual effect therefore, significance is not determined
Economic Development	Continuation of business and economic development	The NSDF Project may provide contracting and supplier opportunities to local and regional businesses	Construction	Employment of personnel, procurement of goods and services, and expenditures from the NSDF Project	The NSDF Projects will competitively procure material and services local and regional communities.	Positive Residual Effect therefore, significance is not determined	Positive Residual Effect therefore, significance is not determined
Housing and Accommodations	Maintenance of commercial accommodation availability	The NSDF Project could increase pressure on commercial accommodations	Construction	Employment of personnel, use of services and infrastructure for NSDF Project	None	Not significant	Not significant

Table 5.10.10-1: Summary of Predicted Residual Effects for Socio-economics Valued Components

Valued Components	Assessment Endpoint	Residual Effects	Project Phase Residual Effect Occurs	Contributing Project Activity	Proposed Mitigation	Significance	
						Application Case	RFD Case
Services and Infrastructure	Maintenance of community services and infrastructure availability and access	Increased road degradation due to increased traffic volume from the transportation of workers, supplies, and equipment.	Construction	Employment of personnel, use of services and infrastructure for NSDF Project	Hauling for transportation of site preparation and construction equipment and construction materials on Highway 17 will be scheduled to reduce traffic volumes.	Not significant	Not significant
		Changes in demand for community services (health, education, protective and emergency services) with respect to the capacity of LSA services to meet the demand	All Project Phases	Employment of personnel, use of services and infrastructure for NSDF Project	Continued implementation and maintenance of compliance with all applicable health and safety standards and CNL's existing environmental, safety and security programs	Not significant	Not significant

This page left intentionally blank

6.0 MALFUNCTIONS AND ACCIDENTS

This section of the Environmental Impact Statement (EIS) for the Canadian Nuclear Laboratories (CNL) Near Surface Disposal Facility (NSDF) Project seeks to understand and characterize potential effects of malfunctions and accidents of the NSDF Project.

Malfunctions and accidents could take place at all phases of the NSDF Project as internally-initiated events (such as equipment failures) and externally-initiated events (including natural hazards). For the purpose of the EIS, malfunctions and accidents associated with the NSDF Project are grouped into two categories:

- radiological malfunctions and accidents; and,
- conventional (non-radiological) malfunctions and accidents.

Radiological accidents refer to those that could result in the release of radioactivity to the environment and potentially affect the environment. Radiological accidents can also result in the release of non-radiological substances in the wastes. For continuity, the assessment of effects from radiological accidents considers both the radiological and non-radiological releases from the wastes. These radiological accident scenarios are evaluated in Section 6.4. Non-radiological accidents refer to those that involve only non-radiological substances and will not have any adverse radiological effects on the environment and humans (e.g., the spill of chemicals, lubricants and oils). These non-radiological accident scenarios are assessed in Section 6.5.

The assessment of potential radiation and radioactivity effects of normal operations of the NSDF Project and anticipated events in post-closure are documented in Section 5.7 Ambient Radioactivity and Ecological Health and Section 5.8 Human Health. Section 5.7 and Section 5.8 also assess the effects of the NSDF Project on ecological and human health from conventional constituents of potential concern.

6.1 Regulatory Context

The Canadian Nuclear Safety Commission (CNSC) Regulatory Policy P-290 (CNSC 2004) includes the following requirements:

- the management of radioactive waste is commensurate with its radiological, chemical and biological hazard to the health and safety of persons and the environment and to national security; and,
- the measures needed to prevent unreasonable risk to present and to future generations from the hazards of radioactive waste are developed, funded and implemented as soon as reasonably practicable.

The CNSC Guide G-320 (CNSC 2006) states that the following have to be considered:

- frequency of natural events; and,
- human-induced environmental changes (e.g., flood, drought, climate change).

Hazards that are considered for the screening analysis can be external or internal. External hazards are defined as hazards that are initiated outside the NSDF Project site or are natural hazards, which are outside of CNL's direct control. These hazards could be in the form of natural hazards (e.g., ice-storms and flooding) or man-made hazards (e.g., human intrusion and aircraft crash). These hazards could have an effect on the containment of radioactive waste and functioning of other systems, structures and components for the NSDF

Project. Internal hazards are defined as hazards that are initiated within the NSDF Project site and are not natural hazards.

6.2 General Approach

The hazard identification involved a literature review of documents and guidance and considers all phases of the NSDF Project (construction, operations, closure and post-closure). No prior assumptions were made as to which hazards should be included or excluded. Some of the documents included as part of the literature review are highlighted below:

- Port Hope Environmental Assessment Study Report (Port Hope Area Initiative 2006);
- Port Granby Environmental Assessment Study Report (CNSC 2009);
- Chalk River Waste Management Areas Hazard Identification Report (AECL 2013);
- Ontario Power Generation’s Low and Intermediate Level Deep Geologic Waste Repository – Preliminary Safety Assessment (NWMO 2011a);
- Idaho CERCLA NSDF Performance Assessment (US DOE 2011);
- CANDU Owners Group (COG) and CNL Operating Experience Reports;
- IAEA Safety Series No. 50-P-7; Table 1 (IAEA 1995);
- IAEA Specific Safety Guide SSG-3 (IAEA 2010);
- IAEA Safety Series No. 50-SG-S9 (IAEA 1984);
- NUREG/CR-2300; Table 10.1 (US NRC 1983);
- NUREG/CR-4839 (US NRC 1992); and,
- NUREG 1407 (US NRC 1991).

The malfunctions and accident assessment follows the steps described below.

1) **Identification of hazards:** A list of external and internal hazards is established and includes both radiological and non-radiological events.
2) **Screening of hazards:** The potential malfunctions and accidents that could occur as a result of credible hazards are identified. Credible hazards are defined as malfunctions and accidents with a reasonable probability of occurrence that could adversely affect workers, the public or the environment. The resulting list of credible events are then grouped into bounding accident scenarios.
3) **Assessment of credible hazards:** For those bounding malfunctions and accident scenarios, a detailed assessment is carried out to determine the significance of adverse effects, if any, taking into account the NSDF Project design, available safety procedures and plans, and past experience and records. Mitigation measures are identified to control or limit adverse effects on the environment; feasibility and economic factors being taken into account.

Further details on the hazard identification and screening process are provided in the Performance Assessment Report (CNL 2017) and Criticality Safety Document (ISR 2017a) for the NSDF Project.

6.3 Project Overview and Identification of Hazards

6.3.1 Project Overview

The NSDF Project includes components and activities related to construction, operations, closure, and post-closure phases for the management of solid radioactive waste that meet the Waste Acceptance Criteria (WAC). The facility is expected to be operational for approximately 50 years and will be expandable to receive up to 1,000,000 cubic metres (m^3) of waste. The footprint of the NSDF Project is approximately 34 hectares (ha). The main physical works related to the NSDF Project are the engineered containment mound (ECM) that will contain the radioactive waste and other wastes that meet the WAC, the wastewater treatment plant (WWTP), and supporting infrastructure.

The design life for the ECM is 500 years, which correlates to design lifespan criteria for similar containment mounds containing radioactive and other mixed wastes in Canada (e.g., Port Hope and Port Granby Long-Term Waste Management Facilities). CNL aims to have the ECM operational in 2020. The NSDF Project will be constructed in sequential stages. All site preparation activities will be completed, including vegetation clearing and earthworks, followed by the construction of the ECM and supporting infrastructure. The construction phase, which includes site preparation, is anticipated to start in 2018 or as soon as the relevant Project regulatory permits and approvals are in place. Construction activities are expected to be completed by March 2020.

The operations phase is anticipated to begin in March 2020 and will end in approximately 2070 (i.e., operating site life of 50 years). The waste streams to be placed in the ECM will primarily originate from operations and decommissioning activities at the CRL property, including legacy radioactive wastes currently stored on site, those from future operations, those which will be generated from the demolition and decommissioning of structures at CRL, and the remediation of some contaminated areas at CRL through to 2070. A few percent of the waste streams to be placed in the ECM will be from off-site sources (e.g., Whiteshell Laboratories and commercial sources, such as hospitals and universities).

Activities associated with the closure phase primarily include those activities necessary to complete the installation of final cover of the ECM, continued treatment of wastewater, including leachate, and establish long-term monitoring systems. Closure activities are expected to start in 2070 and continue through to 2100, after which the NSDF Project will transfer into the post-closure phase. The post-closure phase is defined by two discrete periods: Institutional Control and post-Institutional Control. The Institutional Control period includes implementation of both active and passive control throughout 2100 to 2400 (i.e., 300 years). During Institutional Control, groundwater monitoring and groundwater quality management will continue to demonstrate compliance with the safety case assumptions. Post-Institutional Control occurs after year 2400 and continues indefinitely. Further details on the NSDF Project and specific activities anticipated in each phase are provided in Section 3.0.

6.3.2 Identification of Hazards

Based on a review of the NSDF Project activities, and a review of other similar projects and guidance documents (as identified in Section 6.2), 13 external hazards, 15 internal hazards, and 3 conventional hazards were identified for the NSDF Project. These hazards are listed below:

- External Hazards:
  - earthquakes;
  - flooding;
  - extreme temperatures;
  - snowpack;
  - high winds (including tornadoes);
  - ice storms;
  - lightning;
  - meteorites;
  - human intrusion;
  - accidents at adjacent nuclear facilities;
  - forest fire;
  - aircraft crash; and,
  - glaciation.
- Internal Hazards:
  - geotechnical (i.e. slope instability or subsidence);
  - failure of the ECM containment system due to excessive settlement;
  - failure of cover due to erosion;
  - failure of geomembrane in the cover;
  - failure of liner;
  - release of stored energy (from high energy pipes, valves and fittings that contain gas or liquid);
  - fire or explosion due to gas generation within ECM;
  - internal fire;
  - release of toxic substances from WWTP;
  - failure of WWTP treatment process;
  - container drop;
  - on-site transfer accident;
  - criticality; and,
  - loss of shielding.

- Conventional Hazards:
  - construction and operational accidents;
  - non-radiological effects from fire scenarios; and,
  - on-site spill of fuel, lubricant or hazardous material during construction or operations.

6.4 Radiological Malfunctions and Accidents

In this section, radiological malfunctions and accidents that result from credible initiating events are identified and assessed. Radiological accidents refer to those accidents that could result in the acute release of radioactivity to the environment. Radiological accidents can also result in the release of non-radiological hazardous material from the wastes. For continuity, the assessment of effects from radiological accidents considers both the radiological and non-radiological releases.

6.4.1 Screening of Radiological Hazards

Following the identification of hazards (Section 6.3.2), a screening analysis was completed to remove hazards that are not considered to be credible events for the NSDF Project. Only the operations, closure and post-closure phases of the NSDF Project were considered, as no radiological material would be involved in any malfunction or accident during the construction phase. Based on the findings of the screening process, 13 malfunctions and accidents could not be screened out (i.e., were deemed to be credible events), and therefore, require a consequence assessment. These events are described in Table 6.4.1-1.

The credible malfunction and accident events were grouped into bounding accident scenarios for the consequence assessments; these bounding scenarios are identified in Table 6.4.1-1. A complete description of the screening process, and rationale/results of each hazard evaluation, is provided in the Performance Assessment Report for the NSDF Project (CNL 2017).

Hazards that were considered a normal evolution of the NSDF Project (such as eventual failure of the cover or liner in the post-closure phase [i.e., Post-Institutional Control Period after Year 2400]) are evaluated in Section 5.7 Ambient Radioactivity and Ecological Health and Section 5.8 Human Health; natural hazards (such as glaciation and earthquakes) are evaluated in Section 9.0 Effects of the Environment on the Project. Table 6.4.1-1 provides a guide as to where to find the consequence assessment for each of the bounding hazard scenarios.

Table 6.4.1-1: Bounding Hazard Scenarios for Assessment

Hazards that Require a Consequence Assessment	Bounding Hazard Scenario	Assessment Location in EIS
Operations and Closure Phases		
Lightning and Forest Fires	Fire in Temporary Waste Accumulation Area	Sections 6.4.4 and 6.5.3.2
On-Site Transfer Accident – Fire Engulfing Radioactive Waste Packages	Fire Engulfing Radioactive Waste Packages During On-Site Transfer	Sections 6.4.4 and 6.5.3.2
On-Site Transfer Accident – Damage to Radioactive Waste Package	Damage to Radioactive Waste Package During On-Site Transfer	Section 6.4.4

Table 6.4.1-1: Bounding Hazard Scenarios for Assessment

Hazards that Require a Consequence Assessment	Bounding Hazard Scenario	Assessment Location in EIS
Post-Closure Phase		
Human Intrusion – Acute Exposure from Well Drilling	Human Intrusion – Acute Exposure	Section 6.4.4
Human Intrusion – Chronic Exposure from Living in a House and Farming on Top of the ECM	Human Intrusion – Chronic Exposure	Section 6.4.4
Earthquake	Earthquake	Section 9.0
Glaciation	Glaciation	Section 9.0
Failure of Cover – Due to Erosion	Failure of Cover	Sections 5.7 and 5.8
Extreme Temperature - Causing Erosion of Soil Cover		
Failure of Geomembrane in the Cover – Due to Erosion of Soil Cover or Burrowing Animals – Causing the “Bathtub Effect”		
Failure of Liner	Failure of Liner System	Sections 5.7 and 5.8
Geotechnical – Subsidence		
Operations, Closure and Post Closure Phases		
Criticality	Criticality	Section 6.4.4

6.4.2 Identification of Valued Components

The bounding radiological malfunction and accident scenarios were evaluated to assess the effects to humans and non-human biota. Human receptors included nuclear project workers and members of the public (as per Section 5.8 Human Health). For non-human biota, a list of proposed valued components (VCs) was developed from those that are documented to occur in the vicinity of the NSDF site, have potential for exposure, play a key role in the food web, and represent a variety of habits and trophic levels. In order to determine the potential effect of radiological emissions on the environment, a smaller group of indicator species was chosen to represent VCs selected for assessment.

6.4.3 Radiological Dose Acceptance Criteria

The CNSC has set the regulatory limits for exposure to workers and members of the public (Radiation Protection Regulations [SOR/2000-203]) to ensure that the probability of occurrence of effects is acceptably low. For normal operations, the radiological doses from radionuclide releases and direct radiation exposure must not exceed 50 millisieverts (mSv) annually for the nuclear project workers and 1 mSv annually for members of the public (at the NSDF site boundary) to meet the CNSC regulatory dose limits (SOR/2000-203). In addition, the CRL Licensing Handbook sets an annual dose limit of 0.3 mSv for members of the public (CNL 2016).

For human intrusion scenarios, specifically, the CNSC (2006) states that direct disturbance of disposed radioactive wastes needs to be considered, but only for inadvertent intrusion scenarios. However, neither the legal dose limit of 1 mSv/yr nor the licensing dose limit of 0.3 mSv/yr to members of the public apply to doses resulting from inadvertent human intrusion. For this assessment, the dose criteria from the IAEA Safety Requirements (IAEA 2012) are used; the IAEA postulates that:

- if intrusion is expected to lead to an annual dose of less than 1 mSv, then efforts to reduce the probability of intrusion or to limit its consequences are not warranted;
- if intrusion is expected to lead to annual doses in the range of 1 to 20 mSv, then efforts to optimize the design are warranted to reduce the probability of intrusion and limit the consequences; and,
- if intrusion is expected to lead to annual dose in excess of 20 mSv then alternative disposal options should be considered.

For malfunctions and accidents, CNL's Conduct of Safety Engineering has defined dose acceptance criteria, dependent on the frequency of the event (CNL 2015). These acceptance criteria are provided in Table 6.4.3-1.

Table 6.4.3-1: Dose Acceptance Criteria for Accidents

Frequency Range (Event/year)	Qualitative Event Occurrence Frequency 1	Dose Range (mSv)	
		Nuclear Project Workers	Public
$<10^{-6}$	**Beyond Extremely Rare**; Beyond Design Basis Accident	—	—
10^{-6} to 10^{-4}	**Extremely Rare**; events are not expected to occur during the lifetime of the facility	50 to 100	5 to 100
10^{-4} to 3×10^{-2}	**Rare**; events have slight chance of occurring during the lifetime of the facility	5 to 50	0.5 to 5.0
3×10^{-2} to 3×10^{-1}	**Occasional**; events may occur a few times during the lifetime of the facility	1 to 5	0.1 to 0.5
$>3\times10^{-1}$	**Frequent**; events that are expected to occur several times during the lifetime of the facility	<1 mSv/event	<0.1 mSv/event

For the protection of non-human biota from radiation exposure, the primary concern is the total radiation dose to the organisms resulting in deterministic effects (i.e., threshold below which the effect does not occur). The following dose benchmark values, as recommended in CSA (Canadian Standards Association Group) N288.6-12 (CSA 2012a), will be applied to determine if there are potential effect on non-human biota:

- 100 microgray per hour (µGy/h) for terrestrial biota; and,
- 400 µGy/h for aquatic biota.

If the estimated dose is less than the dose benchmark value, then the radiological risk is considered acceptable; a detailed quantitative risk assessment will be conducted and mitigation measures identified where dose benchmark values are exceeded.

6.4.4 Assessment of Credible Accident Scenarios

The malfunctions and accident scenarios identified in Section 6.4.1 as “credible events” were assessed for potential effects to humans and non-human biota following Canadian and international guidelines. A comprehensive framework for assessing radiological exposure is provided in CSA Standard N288.6-12 (CSA 2012a). Detailed guidance for the calculation of dose to members of the public is provided in CSA Standard N288.1-14 (CSA 2014b) and CSA Standard N288.2-12 (CSA 2012b). In addition, the IAEA provides generic procedures for assessment of a radiological emergency (IAEA 2000). Specific methods and input parameters for each of the scenario assessments are provided in the Performance Assessment for the NSDF Project (CNL 2017).

6.4.4.1 Fire Engulfing Radioactive Waste Packages During the Handling and Emplacement of Wastes within the Engineered Containment Mound

The following accident scenario was developed for the assessment:

- a transportation vehicle carrying ten radioactive waste packages is involved in a postulated fire;
- the fire lasts for one hour; and,
- the nearest public receptors are assumed to 3 kilometres (km) away from the scene, which is the distance from the proposed NSDF Project site to closest cottage residents.

In the event of a fire during the handling and emplacement of wastes within the engineered containment mound, there is a possibility of a release of radionuclides to the environment; however, an event of this nature (as described above) is considered to have an extremely rare likelihood during the lifetime of the NSDF Project. CNL has a Fire Protection Program for the CRL site designed to prevent fire losses, provide responsible fire protection management, and demonstrate compliance to applicable fire protection codes and standards. Fire detection and suppression systems are also included in the NSDF Project design. Further details of this program are provided in Section 3.13.2.9. Should a fire break out at the NSDF Project site, the CRL fire department would be dispatched, who have emergencies procedures in place for responding to potential radiological contamination. Furthermore, following a fire event, environmental monitoring would be conducted to assess any potential contamination and confirm the effectiveness of any remediation activities.

Doses to humans resulting from this postulated fire accident are estimated for the following receptors:

- drivers and other Nuclear Energy Workers on the NSDF Project site; and
- off-site members of the public, consisting of three age classes (infant, child and adult).

Details of the assessment methods (i.e., airborne emission, concentration and dose calculations) and input parameters are provided in the Performance Assessment Report for the NSDF Project (CNL 2017).

As shown in Table 6.4.4-1, doses to workers and members of the public, based on the assumptions used for the accident scenario, are below respective regulatory limits for normal operations, including the 0.3 mSv/yr for members of the public identified in the CRL Licence Condition Handbook (CNL 2016), and CNL’s accident dose criteria for an extremely rare event (CNL 2015). Consequently, doses to the workers and members of the public are below safety criteria and meet safety objectives for the NSDF Project.

Table 6.4.4-1: Doses to Human Receptors Resulting from Fire during the Handling and Emplacement of Wastes within the Engineered Containment Mound

Receptors	Regulatory Criteria For Normal Operations[(a)] (mSv/year)	Accident Criteria Extremely Rare Event[(b)] (mSv)	Dose to Receptors (mSv)
Nuclear Energy Workers	50	50 - 100	5.3×10^{-1}
Public – Adult	1	5 - 100	3.1×10^{-4}
Public - Child	1	5 - 100	3.3×10^{-4}
Public – Infant	1	5 - 100	2.4×10^{-4}

mSv = millisieverts.
(a) *Radiation Protection Regulations* (SOR/2000-203).
(b) Conduct of Safety Engineering (CNL 2015).

Radiological doses to non-human biota were not assessed quantitatively given that the brief duration of exposure (i.e., up to 1 hour) and the implementation of the facility's Fire Protection Program to contain and extinguish the fire would not be expected to result in exposure that would affect non-human biota at the population level. In addition, the assessment of doses to non-human biota is based on the assumption that all indicator species reside in the contaminated area for the entire period of time considered and all food components are taken from the most contaminated area, that is, variation in concentrations across the home ranges is not taken into account. In practice only a small fraction of the overall habitat may become contaminated.

Mobile species such as birds or deer, would only spend a short duration in the vicinity of the area that could be impacted by an accident. Therefore, they wouldn't be exposed to elevated levels of radioactivity resulting from the accident for long periods of time. For those relatively immobile species such as terrestrial plants, the effect would be at the individual level, only in the vicinity of the accidents. In summary, both duration of potential exposure on individual representatives of non-human biota and the number of organisms that may be affected under the accident scenario would be limited. No population level effects would be expected.

Non-radiological exposure to human and non-human biota from a fire scenario is discussed in Section 6.5.3.2.

6.4.4.2 Fire in Temporary Waste Accumulation Area

In the event of a fire at the NSDF Project site during the operations phase, there is a reasonable probability of it to occur in a temporary waste accumulation area (located within the ECM), thereby releasing radionuclides to the environment. The following accident scenario was developed for the assessment:

- 500 packages of radiological waste are involved in the postulated fire in the temporary waste accumulation area;
- the fire lasts for one hour; and,
- the nearest public receptors are assumed to be 3,000 metres (m) away from the scene, which is the distance from the proposed NSDF Project site to the closest cottage residents.

Doses to humans resulting from this postulated fire accident are estimated for the following receptors:

- drivers and other on-site nuclear energy workers; and,
- off-site members of the public, consisting of three age classes (infant, child and adult).

Details of the assessment methods (i.e., airborne emission, concentration and dose calculations) and input parameters are provided in the Performance Assessment Report for the NSDF Project (CNL 2017).

As shown in Table 6.4.4-2, doses to workers and members of the public, based on the assumptions used for the accident scenario, are below CNL's accident dose criteria for an extremely rare event (CNL 2015). Consequently, doses to the workers and members of the public meet safety objectives for the NSDF Project.

Table 6.4.4-2: Doses to Human Receptors Resulting from Fire in Temporary Waste Accumulation Area

Receptors	Accident Criteria Extremely Rare Event[(a)] (mSv)	Dose to Receptors (mSv)
Nuclear Energy Workers	50 – 100	0.68
Public – Adult	5 – 100	0.064
Public - Child	5 – 100	0.056
Public – Infant	5 – 100	0.016

mSv = millisieverts.
(a) Conduct of Safety Engineering (CNL 2015).

As described in Section 6.4.4.1, radiological doses to non-human biota were not assessed quantitatively given that the brief duration of exposure (i.e., up to 1 hour) and the implementation of the facility's Fire Protection Program to contain and extinguish the fire would not be expected to result in exposure that would affect non-human biota at the population level. In addition, the assessment of doses to non-human biota is based on the assumption that all indicator species reside in the contaminated area for the entire period of time considered and all food components are taken from the most contaminated area, that is, variation in concentrations across the home ranges is not taken into account. In practice only a small fraction of the overall habitat may become contaminated.

Mobile species such as birds or deer, would only spend a short duration in the vicinity of the area that could be impacted by an accident. Therefore, they wouldn't be exposed to elevated levels of radioactivity resulting from the accident for long periods of time. For those relatively immobile species such as terrestrial plants, the effect would be at the individual level, only in the vicinity of the accidents. In summary, both duration of potential exposure on individual representatives of non-human biota and the number of organisms that may be affected under the accident scenario would be limited. No population level effects would be expected.

Non-radiological exposure to human and non-human biota from a fire scenario is discussed in Section 6.5.3.2.

6.4.4.3 Damage to Radioactive Waste Packages During the Handling and Emplacement of Wastes within the Engineered Containment Mound

The following accident scenario was developed for the assessment:

- a low-energy impact to radioactive waste packages occurs during the handling and emplacement of wastes within the ECM causing a loss of containment, with ten packages of waste being involved;
- the radionuclides will be released from the damaged packages over an one-hour period prior to mitigation; and,
- the nearest public receptors are assumed to be 3,000 m away from the event, which is the distance from the proposed NSDF Project site to the closest cottage residents.

In the event of damage to radioactive waste packages during the handling and emplacement of wastes in the ECM, there is a possibility of a release of radionuclides to the environment; however, an event of this nature is considered to have an extremely rare likelihood during the lifetime of the NSDF Project. Should a waste package be damaged at the NSDF Project site causing a loss of containment, CRL site personnel would implement all emergency measures required to control the accident and contain the radioactivity. Furthermore, following a waste package accident, environmental monitoring would be conducted to assess any potential contamination and confirm the efficiency of any remediation activities. Canadian Nuclear Laboratories has a number of existing environmental and safety programs for the CRL site to protect employees, the public and the environment, including a Radiation Protection Program, Waste Management Program, Environmental Protection Program and Emergency Preparedness Program. Further details of these programs are provided in Section 3.13.2.

Doses to humans resulting from this postulated damage to waste package accident are estimated for the following receptors:

- drivers and other Nuclear Energy Workers on the NSDF Project site; and,
- off-site members of the public, consisting of three age classes (infant, child and adult).

Details of the assessment methods (i.e., airborne emission, concentration and dose calculations) and input parameters are provided in the Performance Assessment Report for the NSDF Project (CNL 2017).

As shown in Table 6.4.4-3, doses to workers and members of the public, based on the assumptions used for the accident scenario, are below respective regulatory limits for normal operations, including the 0.3 mSv/yr for members of the public identified in the CRL Licence Condition Handbook (CNL 2016), and CNL's accident dose criteria for an extremely rare event (CNL 2015). Consequently, doses to the workers and members of the public are below safety criteria and meet safety objectives for the NSDF Project.

Table 6.4.4-3: Doses to Human Receptors Resulting from Waste Package Breach

Receptors	Regulatory Criteria For Normal Operations[(a)] (mSv/year)	Accident Criteria Extremely Rare Event[(b)] (mSv)	Dose to Receptors (mSv)
Nuclear Energy Workers	50	50 - 100	2.0×10^{-1}
Public – Adult	1	5 - 100	5.4×10^{-5}
Public - Child	1	5 - 100	5.4×10^{-5}
Public – Infant	1	5 - 100	6.2×10^{-5}

mSv = millisieverts.
(a) *Radiation Protection Regulations* (SOR/2000-203).
(b) Conduct of Safety Engineering (CNL 2015).

As described in Section 6.4.4.1, radiological doses to non-human biota were not assessed quantitatively given that the brief duration of exposure (i.e., up to 1 hour) and the implementation of the facility's Fire Protection Program to contain and extinguish the fire would not be expected to result in exposure that would affect non-human biota at the population level. In addition, the assessment of doses to non-human biota is based on the assumption that all indicator species reside in the contaminated area for the entire period of time considered and all food components are taken from the most contaminated area, that is, variation in concentrations across the home ranges is not taken into account. In practice only a small fraction of the overall habitat may become contaminated.

Mobile species such as birds or deer, would only spend a short duration in the vicinity of the area that could be impacted by an accident. Therefore, they wouldn't be exposed to elevated levels of radioactivity resulting from the accident for long periods of time. For those relatively immobile species such as terrestrial plants, the effect would be at the individual level, only in the vicinity of the accidents. In summary, both duration of potential exposure on individual representatives of non-human biota and the number of organisms that may be affected under the accident scenario would be limited. No population level effects would be expected.

Non-radiological exposure to human and non-human biota were not assessed quantitatively given that the primary exposure as a result of this accident would be radiological in nature (e.g., the majority of the waste placed within the ECM is low level radioactive waste and will not have elevated concentrations of hazardous substances). Exposure to elevated levels of non-radiological substances would be expected to be negligible and transient.

6.4.4.4 Human Intrusion

"Human Intrusion" is defined as:

> *Human actions that affect the integrity of a disposal facility and which could potentially give rise to radiological consequences. Only those human actions that result in direct disturbance of the disposal facility (i.e. the waste itself, the contaminated near field or the engineered barrier materials) are considered* (IAEA 2011).

International organizations, such as the IAEA, the International Commission on Radiation Protection (ICRP) and the Organization of Economic Cooperation and Development (OECD), provide the overall framework for

defining human intrusion scenarios. In particular, international organizations provide the following guidance (IAEA 2012; ICRP 1998; OECD/NEA 1995; Seitz et al. 2014):

- Some form of inadvertent human intrusion must be considered in the context of disposal facilities after the end of institutional control period. Intrusion should be assumed to occur at some time following the loss of knowledge about the site and its hazardous contents.
- Analysis should include stylized intrusion scenarios reflecting site-specific conditions, inventory and design. Predictions of actual human behaviour during the post-institutional control period is not required.

The active period of the NSDF Project (construction, operations, and closure phases) will involve a range of activities, such as placement of wastes within the ECM, monitoring, the installation of an engineered cover, and treatment of leachate in the WWTP. During this period there is human action at the NSDF Project site, but it is planned and intentional, and suitable protection will be in place for workers, who will be aware of the nature of the waste. Access to the NSDF Project site will be controlled during operations and throughout institutional control. By definition, inadvertent human intrusion is excluded from these phases of the NSDF Project life-cycle.

The post-closure phase is defined by two discrete periods: Institutional Control and post-Institutional Control. The Institutional Control period includes implementation of both active and passive control throughout 2100 to 2400 (i.e., 300 years). The duration of institutional control is consistent with international and Canadian practice for disposal facilities (e.g., NWMO 2011b). Beyond this period (i.e., Post-Institutional Control), there are no expectations with respect to any ongoing societal control, monitoring or memory of the NSDF Project site.

Using a combination of international and Canadian guidance for the assessment of human intrusion with site-specific conditions resulted in the formulation of the following two scenarios. Further details of the assumptions made in developing these scenarios is provided in the Performance Assessment Report for the NSDF Project (CNL 2017):

1) **Acute exposure from well drilling activities –** involves intrusion into radioactive waste when drilling a well, with exposure to contaminated excavated material.
2) **Chronic exposure from living in a house and farming on top of ECM –** involves intrusion into the radioactive waste while inhabiting a dwelling on top of the ECM, using a residential well drilled into the ECM and mixing of exhumed waste with garden soil.

As part of the Performance Assessment Report for the NSDF Project (CNL 2017) additional scenarios have been evaluated to demonstrate the sensitivity of the analysis.

6.4.4.4.1 Acute Exposure from Well Drilling Activities

In the event of an inadvertent human intrusion from well drilling activities following the institutional control period, there is a possibility of a release of radionuclides to the environment. This could result in exposure to a drilling worker. This scenario includes exposure to contaminated excavated material assumed to occur through inhalation, external exposure and soil ingestion. Doses to a drilling worker were calculated, using RESRAD OFFSITE 3.1, at different times following the end of institutional control; the highest estimated exposure of drilling workers predicted to occur if intrusion is carried out is immediately after the end of Institutional control. The key pathways are inhalation, exposure to contaminated land, and incidental ingestion of contaminated soil.

Assessment methods, including inhalation rates, transfer factors, consumption rates and other exposure parameters are consistent with the CSA standard N288.1-14 (CSA 2014a); otherwise, RESRAD (US NRC 2015) default values were used. The waste inventory concentrations and other key modelling parameters are provided in the Performance Assessment Report for the NSDF Project (CNL 2017).

As shown in Table 6.4.4-4, doses to drilling workers, based on the assumptions used for the acute exposure human intrusion scenario, are less than 1 mSv/yr, which is the lower dose benchmark for human intrusion. Consequently, doses to the potential intruders are below safety criteria for intrusion and meet the overall safety objectives for the NSDF Project.

Table 6.4.4-4: Dose to Drilling Worker from Acute Exposure

Time After the End of Institutional Control (years)	Total dose (mSv)
0	2.4×10^{-2}
100	2.1×10^{-2}

mSv = millisieverts.

Radiological doses to non-human biota were not assessed quantitatively; however, an approximation of the dose received by non-human biota was calculated considering the total doses estimated to drilling workers. The exposure scenario for drilling workers is described in the Performance Assessment Report for the NSDF Project (CNL 2017); in brief, drilling workers were assumed to be directly exposed to drilling cuttings for three 8-hour days. Considering that the radiological dose criterion to non-human terrestrial biota is 100 µGy/hour (see Section 6.4.3), the doses estimated for humans were converted to an hourly dose (i.e., 0.001 mSv/hour = 1 µGy/hour; note that 1 Sv = 1 Gy for gamma exposure). The approximate hourly dose to terrestrial biota is lower than the radiological dose criterion for protection of non-human biota; therefore, adverse effects to non-human biota due to the acute human intrusion scenario are not expected.

6.4.4.4.2 Chronic Exposure from Living in a House and Farming on Top of the Engineered Containment Mound

In the event of an inadvertent human intrusion from living and farming on top of the ECM during the Post-Institutional Control period (i.e., after the year 2400), there is a possibility of a release of radionuclides to the environment. This could result in chronic exposure to a farmer. Doses to farm residents were calculated using RESRAD OFFSITE 3.1. Assessment methods, including inhalation rates, transfer factors, consumption rates and other exposure parameters are consistent with the CSA standard N288.1-14 (CSA 2014a); otherwise, RESRAD (US NRC 2015) default values were used. The waste inventory concentrations and other key modelling parameters are provided in the Performance Assessment Report for the NSDF Project (CNL 2017). Doses to farm residents, based on the assumptions used for the chronic exposure human intrusion scenario, are provided in Table 6.4.4-5.

Table 6.4.4-5: Dose to Farm Resident from Chronic Exposure

Time After the End of Institutional Control (years)	Total dose (mSv/year)
0	1.3
1	1.2
10	1.5
100	1.3
500	1.4
1,000	1.8
5,000	1.2
10,000	1.8
66,107	5.0
100,000	4.7

Exposure pathways include inhalation, external exposure, soil ingestion, and ingestion of contaminated food (i.e., beef, milk, and plants). The key pathways are inhalation of radon, consumption of contaminated plants and exposure to contaminated land. Based on these results, the maximum dose to human receptors resulting from inadvertent human intrusion from living and farming on top of the waste is 5.0 mSv/y, occurring in the approximately 66,000 years following the end of the Institutional Control period (i.e., Year 2400). This estimate is likely to substantially overestimate potential exposure to an intruder because it results from a very conservative assumption that no loss of inventory occurs in the period from placement of waste into the ECM until intrusion occurs some tens of thousands of years later. Further details of this evaluation are provided in the Performance Assessment Report for the NSDF Project (CNL 2017).

Based on guidance in IAEA (2012), the results indicate that reasonable efforts are warranted during design of the NSDF Project to reduce the probability of intrusion or limit its consequences. A number of measures will be implemented through design to decrease the chance of inadvertent human intrusion into the waste. For example, the NSDF Project will be designed to provide a range of protective measures, including:

- site recognition;
- waste recognition;
- markers and placards; and,
- passive barriers.

As indicated for the acute human intrusion scenario, radiological doses to non-human biota were not assessed quantitatively; however, an approximation of the dose received by non-human biota was calculated considering the total doses estimated to farm residents. The exposure scenario for farm residents is described in the Performance Assessment Report for the NSDF Project (CNL 2017). In brief, farm residents were considered to be directly exposed to drilling cuttings and water from a drilled well, and indirectly exposed to ambient radioactivity for a full year, which is likely an overestimate of the exposure that would be received by terrestrial biota. Considering that the radiological dose criterion to non-human terrestrial biota is 100 µGy/hour (see

Section 6.4.3), the doses estimated for humans were converted to an hourly dose (i.e., 0.0006 mSv/hour = 0.6 µGy/hour; note that 1 Sv = 1 Gy for gamma exposure). The approximate hourly dose to terrestrial biota is lower than the radiological dose criterion for protection of non-human biota; therefore, adverse effects to non-human biota due to the chronic human intrusion scenario are not expected.

6.4.4.5 Criticality

A Criticality Safety Analysis was performed separately from this analysis and is documented in the NSDF Criticality Safety Document (ISR 2017a). The Criticality Safety Analysis complies with CNSC regulatory requirements for nuclear criticality safety (CNSC 2011) and demonstrates that conditions at the NSDF Project remain below Upper Subcritical Limits under all normal and credible abnormal conditions throughout all phases of the NSDF Project lifecycle. The Criticality Safety Analysis was supported by a Hazard Identification Report (ISR 2017b), which assessed the potential for changes in parameters that affect criticality safety. As a result of the Criticality Safety Analysis, criticality safety controls were created to ensure that the Double Contingency Principle applies. The Double Contingency Principle states that process designs should incorporate sufficient factors to require at least two unlikely, independent and concurrent changes in process conditions before a criticality accident is possible (CNSC 2011). Operating limits and conditions were also established for the NSDF Project to provide criticality safety.

6.5 Conventional (Non-Radiological) Malfunctions and Accidents

In this section, conventional malfunctions and accidents that result from credible initiating events are identified and assessed. Non-radiological accidents refer to those that involve only non-radiological substances and will not have any adverse radiological effects on the environment and humans.

6.5.1 Screening of Non-Radiological Hazards

Following the identification of hazards (Section 6.3.2), a screening analysis was completed to remove conventional hazards that are not credible events for the NSDF Project. Hazards were screened out if:

- the hazard is not applicable to the waste, NSDF design, or CRL site geographical setting;
- if there is an extremely low likelihood that the hazard would occur; or,
- the hazard would have low consequence and negligible effect.

Based on the findings of the screening process, two malfunction and accident scenarios were identified as requiring a consequence assessment: a spill of a fuel, lubricant or hazardous material on the NSDF Project site; and fire in temporary waste accumulation area (i.e., within the ECM).

6.5.2 Identification of Valued Components

The conventional accident scenario was assessed to investigate the effects to humans and non-human biota. Similar to the assessments for radiological malfunctions and accidents, human receptors included nuclear project workers and members of the public. Non-human biota, discussed in Section 6.4.2, are represented by indicator species that have been selected for the assessment.

6.5.3 Assessment of Credible Accident Scenarios

6.5.3.1 Spills

Malfunction and accident scenarios involving a spill could include a vehicle accident, failure of storage equipment (i.e., a storage tank), or operational errors on the NSDF Project site. For the purpose of the assessment, the likely maximum volume of a spill is assumed to be approximately 4,500 litres (L) of diesel fuel, 200 L of a chemical or hazardous material, and 100 L of a lubricant or oil. The consequences of a spill would be the same, regardless of the project phase; therefore, the discussion below applies to each of the construction, operations, closure, and post-closure phases for the NSDF Project.

The 4,500-L diesel fuel tank will meet the requirements in the Environmental Code of Practice for Aboveground Storage Tank Systems Containing Petroleum Products. The aboveground tank system includes secondary containment, the piping and product transfer area, and associated equipment to ensure that equipment is designed and installed properly in order to limit the possibility of product spills and leaks in accordance with the requirements of the Environmental Code and the National Fire Code.

All chemicals, fuels, and lubricants will be stored and used in accordance with applicable regulatory requirements. In addition, the construction contractor and/or NSDF Project personnel will ensure the appropriate number, location, and accessibility of first aid kits, fire protection equipment, and spill control devices (i.e., spill placard, absorbent socks, absorbent pads), particularly in areas of storage and re-fuelling or application. All vehicles on the NSDF Project site are equipped with spill kits. Vehicle maintenance, refuelling, and storage of chemicals, fuels, and lubricants will be stored and used in designated areas, and at least 30 m away from any waterbodies or wetlands. Where designated areas are established, they are to be appropriately fenced (or otherwise delineated), identified by signage, and developed in a manner so as to contain spills and leaks. An Emergency Protection Plan will be developed to provide rapid and competent response to spills that may occur from the NSDF Project. Aspects of this plan include instructions and procedures for quick detection, control, and management of spills occurring on the NSDF Project site.

Spills on the NSDF Project site or along access roads can cause changes to air, groundwater, surface water and soil quality, which can subsequently, affect aquatic and terrestrial biodiversity. Several mitigation practices and policies are planned to reduce the potential for spills and leaks to limit the effects of spills and leaks on the environment.

In the event of a spill, equipment used to respond to the spill would result in greenhouse gas (GHG), dust and air emissions that may interact with air quality. Fuels represent the largest potential spill volume. Spilled fuel also has the potential to volatilize; however, the majority of fuel used is diesel, which is less likely to volatilize than gasoline. The effects from the clean-up of such a spill are likely to be localized and not measurable. Chemical or lubricant spills would also be of a small volume (200 L and 100 L, respectively) and would represent a localized issue even if they volatilize. Emissions associated with the support and response equipment would be less than those predicted for the construction and operations phase; consequently, negligible increases to GHG, air or dust emissions are expected.

The drainage area for the NSDF Project site primarily slopes from east to west and discharges to wetlands along the western limits. A perimeter ditch will be constructed around the base of the ECM to collect surface runoff from the ECM and convey it to either surface water management pond #2 or #3. A perimeter access road will be located adjacent to and sloped towards the perimeter ditch. Consequently, any spills occurring in the vicinity of

the ECM or along the road would be directed to the perimeter ditch that would ultimately flow to the surface water management ponds. Should a spill occur and collect in the perimeter ditch or surface water management pond, the water would be held, monitored, and treated as necessary prior to release to the environment. If treatment was not available (i.e., if a spill were to occur prior to the commissioning of the WWTP), the water would be transferred to containers and disposed of at a licensed waste facility.

As described above, fuel tanks will be designed with sufficient secondary storage containment to mitigate any accidental releases to the environment. All chemicals, fuels, and lubricants will be stored and used in accordance with applicable regulatory requirements. In addition, all vehicles will be fuelled in the designated fuelling area and outfitted with spill kits to mitigate effects of any accidental spills. The NSDF Project site has a minimum set back distance of 30 m from all waterbodies and wetlands. The likelihood a spill would bypass the surface water collection area or overtop the collection ditch and flow over 30 m towards the wetland are extremely low. In addition, vegetation will have been cleared in the early stages of the site preparation during construction phase and animals will likely avoid the area once construction activities commence due to lack of habitat and the presence of workers.

Implementation of the Environmental Protection Plan (EPP) to be developed for the NSDF Project will facilitate rapid and competent response to spills by providing instructions and procedures for quick detection, control, and management of spills occurring on the NSDF Project site. Therefore, NSDF Project personnel would quickly identify the spill and immediately notify emergency response personnel. Implementation of the above mentioned mitigation are expected to reduce the likelihood and extent of spills occurring on the NSDF Project site. Overall, changes to air, groundwater, surface water and soil quality, and subsequent, adverse effects on aquatic and terrestrial biodiversity, are not expected from spills.

Implementation of the above mentioned mitigation are expected to reduce the likelihood and extent of spills occurring on the NSDF Project site. Overall, it is anticipated that there will be no unacceptable risks to the environment, workers or members of the public from a spill at the NSDF Project site.

6.5.3.2 Fire in Temporary Waste Accumulation Area

The non-radiological assessment considered the fire accident scenario for atmospheric effects, which considers the environmental impacts of hazardous materials being released if a fire were to engulf bulk material in the staging area during the operations phase of the NSDF Project. The details of the fire accident scenario are provided in the Performance Assessment Report for the NSDF Project (CNL 2017). It is noted that the air quality discipline assessed the predicted non-radiological concentrations in air emissions during the operations phase of the Project; the concentrations of the modelled parameters are below applicable air quality guidelines and/or standards (see Section 5.2.1.6.2) and such were not considered further for human health.

Given that the fire accident scenario estimated the concentrations of non-radiological substances in air for a 1-hour averaging period, health-based guidelines protective of 1-hour exposure times were used. As with the selection of screening guidelines for water quality, federal and provincial guidelines were consulted preferentially. However, federal guidelines were only available for nitrogen dioxide, and no 1-hour provincial guidelines are available. Alternative guidelines were obtained from the Texas Commission on Environmental Quality, which has a large database providing short-term (1-hour) and long-term (annual) screening levels for air quality. The selected guidelines are described in Section 5.2.1.

For the fire accident scenario, the predicted concentrations of non-radiological substances considering a 1-hour averaging time were compared to the available 1-hour health-based guidelines for air (Table 6.5.3-1).

Table 6.5.3-1: Comparison of Estimated 1-hour Concentrations of Non-Radiological Substances in Air during the Fire Accident Scenario to 1-hour Health-Based Guidelines

Hazardous Substance	Health-Based Guideline (g/m^3)	Concentration for workers on-site (g/m^3)	Concentration for public located 3,000 m from the site (g/m^3)
Aluminum	1.67×10^{-4}	**9.46×10^{-2}**	5.78×10^{-6}
Ammonium	No values Ammonia: 6.00×10^{-4}	1.22×10^{-4}	7.44×10^{-9}
Aroclor 1260	No values Aroclor 1254: 1.00×10^{-5}	3.25×10^{-5}	1.99×10^{-9}
Arsenic	1.00×10^{-5}	4.86×10^{-6}	2.97×10^{-10}
Barium	1.70×10^{-5}	1.00×10^{-6}	6.14×10^{-11}
Bismuth	1.67×10^{-4}	6.57×10^{-8}	4.01×10^{-12}
Boron	5.00×10^{-5}	1.69×10^{-5}	1.03×10^{-9}
Cadmium	1.80×10^{-5}	**4.07×10^{-3}**	2.49×10^{-7}
Calcium	Surrogate is PM; no 1-hour value available	2.58×10^{-3}	1.58×10^{-7}
Carbonate	Surrogate is PM; no 1-hour value available	2.16×10^{-3}	1.32×10^{-7}
Cesium	2.00×10^{-5}	1.63×10^{-6}	9.98×10^{-11}
Chlorine	1.50×10^{-5}	**9.06×10^{-4}**	5.54×10^{-8}
Chromium	1.20×10^{-5}	**3.07×10^{-2}**	1.87×10^{-6}
Citrate	Surrogate is PM; no 1-hour value available	9.63×10^{-1}	5.89×10^{-5}
Cobalt	7.00×10^{-7}	**7.44×10^{-5}**	4.54×10^{-9}
Copper	3.30×10^{-5}	**5.86×10^{-3}**	3.58×10^{-7}
Cyanide	6.70×10^{-5}	3.50×10^{-6}	2.14×10^{-10}
Ethylene Diamine Tetraacetic Acid (EDTA)	Surrogate is PM; no 1-hour value available	2.67×10^{-6}	1.63×10^{-10}
Iodine	1.00×10^{-5}	**1.41×10^{-2}**	8.63×10^{-7}
Iron	3.30×10^{-5}	**3.61×10^{-3}**	2.21×10^{-7}
Lead	No value defined	1.75×10^{-1}	1.07×10^{-5}
Lithium	7.00×10^{-6}	7.42×10^{-8}	4.53×10^{-12}
Magnesium	1.33×10^{-4}	**4.88×10^{-4}**	2.98×10^{-8}
Manganese	7.00×10^{-6}	**5.72×10^{-3}**	3.50×10^{-7}

Hazardous Substance	Health-Based Guideline (g/m^3)	Concentration for workers on-site (g/m^3)	Concentration for public located 3,000 m from the site (g/m^3)
Mercury	2.50×10^{-7}	**3.77×10^{-3}**	2.31×10^{-7}
Molybdenum	1.00×10^{-4}	3.33×10^{-8}	2.03×10^{-12}
Niobium	1.67×10^{-4}	**2.64**$\times10^{-2}$	1.61×10^{-6}
Nickel	1.10×10^{-6}	1.11×10^{-7}	6.76×10^{-12}
Nitrate	Surrogate is PM; no 1-hour value available	9.27×10^{0}	5.67×10^{-4}
Nitric Acid	5.00×10^{-5}	**3.74×10^{-1}**	2.29×10^{-5}
Nitrogen Dioxide	4.00×10^{-4}	1.76×10^{-2}	1.08×10^{-6}
Oxalate	No value defined	**1.68×10^{-1}**	1.03×10^{-5}
Phosphate	Surrogate is PM; no 1-hour value available	1.82×10^{0}	1.11×10^{-4}
Phosphorus	3.00×10^{-6}	**1.24×10^{-2}**	7.58×10^{-7}
Potassium	6.70×10^{-5}	**8.29×10^{-2}**	5.06×10^{-6}
Silicon	Surrogate is PM; no 1-hour value available	1.60×10^{-5}	9.81×10^{-10}
Silver	3.00×10^{-7}	**5.08×10^{-7}**	3.10×10^{-11}
Sodium	No value defined	6.42×10^{-2}	3.93×10^{-6}
Strontium	6.70×10^{-5}	1.52×10^{-6}	9.26×10^{-11}
Sulphate	Surrogate is PM; no 1-hour value available	1.69×10^{-3}	1.03×10^{-7}
Sulphur	6.70×10^{-5}	**4.58×10^{-2}**	2.80×10^{-6}
Tantalum	1.67×10^{-4}	9.07×10^{-5}	5.54×10^{-9}
Tantalum Carbide	No values Tantalum chloride: 1.67×10^{-4}	6.66×10^{-7}	4.07×10^{-11}
Tellurium	3.00×10^{-6}	**5.54×10^{-6}**	3.38×10^{-10}
Thorium	NV	6.85×10^{-2}	4.19×10^{-6}
Tin	6.70×10^{-5}	1.21×10^{-6}	7.40×10^{-11}
Titanium	1.67×10^{-4}	4.35×10^{-6}	2.66×10^{-10}
Titanium Carbide	No values Titanium chloride: 1.67×10^{-4}	8.07×10^{-6}	4.93×10^{-10}
Uranium	2.00×10^{-6}	**3.57×10^{-4}**	2.18×10^{-8}
Zinc	6.70×10^{-5}	3.76×10^{-5}	2.30×10^{-9}
Zirconium	1.67×10^{-4}	8.60×10^{-5}	5.26×10^{-9}

Concentrations greater than the health-based guidelines are shown with bold font.

As shown above, the estimated 1-hour concentrations of non-radiological substances for members of the public for the fire accident scenario met their respective health-based guidelines. However, several non-radiological substances had estimated concentrations greater than their selected health-based guidelines for on-site workers. As described in the Performance Assessment (CNL 2017), given the Fire Protection Plan that is in place at the NSDF Project site, on-site workers are required to don safety equipment including respirators. Therefore, potential human health risks associated with this scenario are considered to be negligible.

Non-radiological exposure to non-human biota were not assessed quantitatively given that the primary exposure as a result of this accident would be radiological in nature (e.g., the majority of the waste placed within the ECM is low level radioactive waste and will not have elevated concentrations of hazardous substances). As described in Section 6.4.4.1, given the brief duration of exposure (i.e., up to 1 hour) and the implementation of the facility's Fire Protection Program to contain and extinguish the fire, it would not be expected to result in exposure that would affect non-human biota at the population level. In addition, the assessment of doses to non-human biota is based on the assumption that all indicator species reside in the contaminated area for the entire period of time considered and all food components are taken from the most contaminated area, that is, variation in concentrations across the home ranges is not taken into account. In practice only a small fraction of the overall habitat may become contaminated.

Mobile species such as birds or deer, would only spend a short duration in the vicinity of the area that could be impacted by an accident. Therefore, they wouldn't be exposed to elevated levels of non-radiological substances resulting from the accident for long periods of time. For those relatively immobile species such as terrestrial plants, the effect would be at the individual level, only in the vicinity of the accidents. In summary, both duration of potential exposure on individual representatives of non-human biota and the number of organisms that may be affected under the accident scenario would be limited. No population level effects would be expected.

6.6 Emergency Preparedness

Based on the assessment, it is concluded that adverse effects of the malfunctions and accidents identified will be unlikely. Activities involving the handling, processing, transportation and storage of radioactive materials be performed in a manner that protects the workers, the public and the environment, and ensures compliance with applicable regulatory and licence basis requirements and as low as reasonably achievable (ALARA). In addition, radiological releases will be first prevented, then mitigated, and finally accommodated through design, operating procedures, training and administrative controls (see Section 3.13.1 for further details).

As described in Section 3.13.2, the following environmental programs and emergency response procedures will be in effect for the NSDF Project:

- Radiation Protection Program;
- Environmental Protection Program;
- Waste Management Program;
- Occupational Safety and Health Program;
- Emergency Preparedness Program;
- Nuclear Criticality Safety Program;
- Physical Security Program;

- Nuclear Materials and Safeguards Management Compliance Program; and,
- Fire Protection Program.

In particular, the control and safe handling of hazardous materials and nuclear materials are covered under CNL's Waste Management Program and Nuclear Materials and Safeguards Management Compliance Program, respectively. Emergency procedures are covered under CNL's Emergency Preparedness Program and Fire Protection Program.

The Emergency Preparedness Program comprises planning and response elements to ensure that processes are in place to control and mitigate the consequences of an emergency (whether related to a nuclear/radiological or conventional incident) both on- and off-site. In accordance with the Ontario Nuclear Emergency Plan, the program includes infrastructure, assigned response staff and other resources, and periodic exercises to test and demonstrate emergency preparedness. The Emergency Preparedness Program takes into consideration guidance provided in the CNSC's Nuclear Emergency Preparedness and Response document (CNSC 2016).

The CRL site is served by its own internal Emergency Response Team. In addition, a comprehensive on- and off-site Emergency Response Plan is in place. Response teams have been trained and are equipped to respond to potential emergencies such as personal injury, fire or non-routine releases of radioactivity. For example, a spill of diesel fuel would be mitigated by quickly assessing the situation for any immediate health and safety risks to the spills response team, NSDF Project workers and the public by controlling the source of the spill and notifying appropriate regulatory agencies, by deploying appropriate spill containment measures to surround and contain the spill, and finally, by implementing an effective cleanup plan that would likely involve the use of specialized equipment to pump the diesel fuel into secure containers. These measures would contain a spill within the NSDF Project site.

Changes to the above programs are not anticipated as a result of the NSDF Project; however, additional procedures may be added. CNL will establish an NSDF Project-specific EPP, including emergency response procedures. This NSDF Project EPP establishes practices for safe and environmentally sound management of the facility during construction, operational, closure and post-closure phases. This plan establishes practices and performance criteria to prevent unacceptable dispersal of radioactive and non-radioactive materials through environmental pathways and provides mechanisms for early detection of releases of radioactivity, as well as monitoring for both radioactive and non-radioactive emissions. This plan also includes information on how long-term behaviours of the waste are evaluated with respect to environmental protection and is developed to so that applicable regulatory requirements are met.

Emergency response procedures for the NSDF Project are prepared to address potential emergencies, such as fires, radioactivity release, and operational accidents that can affect the public, employees, and the safety of the facilities, and provides a response guide for such events. During each design phase, the appropriate hazard analysis shall be undertaken. The design demonstrates through its evolution that these hazards are appropriately assessed and mitigated. Proper emergency protocols are instituted to protect the safety of all personnel on site and to protect the general public and the environment. This includes an Emergency Response Program with routine emergency drills including fire safety, contamination release response, and other events. The NSDF personnel will alert emergency response personnel to mobilize as required to respond in the event of emergencies.

6.7 Conclusions

Malfunctions and accidents could take place throughout all phases of the NSDF Project as internally-initiated events (e.g., equipment failures) and externally-initiated events (including natural hazards). Based on a review of the NSDF Project activities, and a review of other similar projects and guidance documents, 28 radiological hazards and 3 non-radiological hazards were identified.

Based on the findings of the radiological screening process, 13 malfunctions and accidents could not be screened out (i.e., were deemed to be credible events). These credible malfunction and accident events were grouped into bounding accident scenarios and a consequence assessment was completed. Hazards that were considered a normal evolution of the NSDF Project (such as failure of the cover or liner in post-closure) are evaluated in Sections 5.7 and 5.8; natural hazards (such as glaciation and earthquakes) are evaluated in Section 9.0. The bounding accident scenarios described in this section of the EIS are listed below.

Operations and Closure Phases

- A fire could occur during the handling and emplacement of wastes within the engineered containment mound engulfing radioactive waste packages on the NSDF Project site.
- A fire in the temporary waste accumulation area on the NSDF Project site.
- Damage to radioactive waste packages could occur during the handling and emplacement of wastes within the engineered containment mound.

Post-closure Phase

- Inadvertent human intrusion of the ECM could occur following the end of institutional control, including:
  - acute exposure from well drilling; and,
  - chronic exposure from living in a house and farming on top of the ECM.

The above credible malfunctions and accident scenarios were assessed for their potential effects to humans and non-human biota following Canadian and international guidelines. Specific methods and input parameters for each of the scenario assessments are provided in the Performance Assessment for the NSDF Project (CNL 2017).

In the waste package transfer and fire accident scenarios on the NSDF Project site, doses to Nuclear Energy Workers and/or members of the public are below safety criteria and meet safety objectives for the NSDF Project. Given the brief duration of exposure (i.e., up to 1 hour) and the implementation of the facility's Fire Protection Program to contain and extinguish the fire, radiological doses would not be expected to affect non-human biota at the population level. Non-radiological exposure to human and non-human biota from damage to radioactive waste packages during an on-site transfer on the NSDF Project site would be expected to be negligible and transient. Non-radiological exposure to human and non-human biota from the fire scenarios are discussed below with the conventional malfunctions and accidents.

The human intrusion assessment includes consideration of two exposure scenarios: acute and chronic. The acute exposure scenario considers intrusion into waste when drilling a well. The key exposure pathways are inhalation, exposure to contaminated land, and incidental ingestion of contaminated soil. The estimated dose to

drilling workers is less than the lower intrusion dose benchmark of 1 mSv/y. For terrestrial biota, the approximate hourly dose is lower than the radiological dose criterion for protection of non-human biota. Therefore adverse effects to human and non-human biota due to the acute intrusion scenario are not expected.

The chronic exposure scenario considers a human intruder living and farming on top of the waste. The key exposure pathways are inhalation of radon, consumption of contaminated plants, and exposure to contaminated land. Based on the results, the maximum dose to human receptors resulting from inadvertent human intrusion from living and farming on top of the waste is 5.0 mSv/y, occurring in the year 66,000 following the end of the Institutional Control period. This estimate is likely to substantially overestimate potential exposure to an intruder because it results from a very conservative assumption that no loss of inventory occurs in the period from placement of waste into the ECM until intrusion occurs some tens of thousands of years later. The results indicate that reasonable efforts are warranted during design of the NSDF Project to reduce the probability of intrusion or limit its consequences. Mitigation measures developed for the NSDF Project to hinder intrusion include permanent markers and placards identifying the ECM and waste, and passive barriers. For terrestrial biota, given that the approximate hourly dose is lower than the radiological dose criterion for the protection of non-human biota, and the conservative assumptions used in the assessment, adverse effects to non-human biota due to the chronic human intrusion scenario are not expected.

Based on the findings of the non-radiological screening process, two malfunction and accident scenarios could not be screened out: a spill of a fuel, lubricant or hazardous material on the NSDF Project site and a fire in a temporary waste accumulation area. For spills, implementation of mitigation measures are expected to reduce the likelihood and extent of spills occurring on the NSDF Project site; therefore, no unacceptable risks to the environment, workers or members of the public from a spill at the NSDF Project site are anticipated.

For the fire in a temporary waste accumulation area scenario, the estimated 1-hour concentrations of non-radiological substances for members of the public meet their respective health-based guidelines. Exposure of on-site workers to non-radionuclides during a fire accident is expected to be negligible, as on-site workers would be required to don safety equipment (as per the Fire Protection Plan), including respirators. Given the brief duration of exposure (i.e., up to 1 hour) and the implementation of the facility’s Fire Protection Program to contain and extinguish the fire, it would not be expected to result in exposure that would affect non-human biota at the population level.

CNL has a number of environmental programs and emergency response procedures in place for the operations at the CRL site, and will be implemented for the NSDF Project. In particular, the control and safe handling of hazardous materials and nuclear materials are covered under CNL’s Waste Management Program and Nuclear Materials and Safeguards Management Compliance Program, respectively. Emergency procedures are covered under CNL’s Emergency Preparedness Program and Fire Protection Program. The potential effects of a malfunction or accident can be further reduced or controlled through implementation of mitigation measures; the hazard analysis was incorporated into the design process to integrate mitigations directly into the NSDF Project design. Changes to the above programs are not anticipated as a result of the NSDF Project; however, additional procedures may be added. CNL will establish an NSDF Project-specific EPP, including emergency response procedures.

7.0 SUMMARY OF CUMULATIVE EFFECTS

7.1 Introduction and Approach

The *Canadian Environmental Assessment Act, 2012* (CEAA 2012) requires that each environmental assessment of a designated project take into account any cumulative environmental effects that are likely to result from the designated project in combination with the environmental effects of other physical activities that have been or will be carried out (the Agency 2015). The method for assessment of cumulative effects is outlined in Section 5.1 and is consistent with the Canadian Nuclear Safety Commission (CNSC) *Generic EIS Guidelines* and the Agency's *Technical Guidance for Assessing Cumulative Effects under the Canadian Environmental Assessment Act, 2012* (the Agency 2014). Cumulative effects are assessed using the same approach used for the project-specific effects analysis. The approach follows the same five general steps outlined in the Cumulative Effects Technical Guidance document (the Agency 2014):

- **Step 1: Scoping:**
  - identifying valued components (VCs; see Section 5.1.2 Valued Components);
  - determining spatial boundaries (see Section 5.1.3.1 Spatial Boundaries);
  - determining temporal boundaries (see Section 5.1.3.2 Temporal Boundaries); and,
  - examining physical activities that have been and will be carried out (see Section 5.1.3.3 Assessment Cases).
- **Step 2: Analysis** (see Section 5.1.5 Project Interactions and Mitigation and 5.1.6 Residual Effects Analysis).
- **Step 3: Mitigation** (see Section 5.1.5 Project Interactions and Mitigation and 5.1.6 Residual Effects Analysis).
- **Step 4: Significance** (see Section 5.1.8 Residual Effects Classification and Determination of Significance).
- **Step 5: Follow-up** (see Section 5.1.9 Monitoring and Follow-up).

The purpose of the cumulative effects assessment is to evaluate the contribution of effects from the Near Surface Disposal Facility (NSDF) Project (i.e., Application Case) in combination with previous, existing, or reasonably foreseeable projects or activities in the region (i.e., Reasonably Foreseeable Developments [RFD] Case) that may overlap spatially (i.e., the same geographic area) and temporally (i.e., over time). Reasonably foreseeable projects or activities in the region that have not yet been approved or developments and activities that are currently under application review, or that have officially entered a regulatory application process are considered reasonably foreseeable. The cumulative effects assessment considers all primary pathways that are likely to result in detectable changes in measurement indicators, and subsequent residual effects on VCs, after implementing environmental design features and mitigation.

The VCs requiring an analysis under the RFD Case are determined by understanding whether the residual effects from the NSDF Project and one or more additional developments (or activities) overlap or interact with the temporal or spatial distribution of the VC. For some VCs there is no potential for cumulative effects to environmental components, because there is no overlap with other developments. Where potential cumulative effects from the RFD Case are identified for these VCs, these effects were assessed using the same approach used for the project-specific effects analysis.

7.2 Reasonably Foreseeable Projects

As described in Section 7.1, the NSDF Project has the potential to interact with past, existing and reasonably foreseeable projects or activities in the region. Table 7.2-1 provides a summary of the other projects considered in the RFD Case. The potential effects of these projects and activities were then further considered as to whether they were likely to overlap with VCs affected by the NSDF Project.

Table 7.2-1: Reasonably Foreseeable Developments considered in the Assessment

Type of Project	Location	Examples	Timeframe
New/upgraded R&D Facilities	Chalk River Laboratories (CRL)	Advanced Nuclear Material Research Centre Tritium Laboratory Nuclear Fuel Fabrication Facility (facility upgrade)	2018 and onward
New Support Infrastructure	CRL	Office Buildings, Maintenance facility,	2016 to 2026
Infrastructure Decommissioning	CRL	Over 120 buildings on CRL Site including nuclear laboratories and conventional buildings	2016 to 2026
Environmental Remediation	CRL	Remediation of affected lands and non-operating waste management areas (WMAs). Waste management areas include WMA A and Liquid Dispersal Areas adjacent to the NSDF.	On-going
In-Situ Decommissioning of NPD	Rolphton	The Nuclear Power Demonstration (NPD) Closure Project (in-situ decommissioning of the Nuclear Power Demonstration Waste Facility (NPDWF) in Rolphton, Ontario)	2018-2020
Construction of new infrastructure at Garrison Petawawa	Petawawa	Construction of new buildings and services (e.g. integrated health centre, vehicle wash facility, replacement buildings)	2016 and onward

7.3 Summary of Cumulative Effects

7.3.1 Atmospheric Environment

As described in Section 5.2, there are no reasonably foreseeable future developments expected in the atmospheric environment Regional Study Area (RSA) (i.e., within 10 kilometres (km) of the CRL site) other than the decommissioning of the remaining CRL structures. The waste from the decommissioning of the CRL structures will be placed in the NSDF and the Application Case assessed for the operations phase considers the transport of this waste for disposal in the Engineered Containment Mound (ECM). New/upgrades to research and development facilities, new support infrastructure and decommissioning activities will involve similar equipment used during the construction phase of the NSDF Project, and are expected implement similar mitigation to limit vehicle and equipment exhaust, and fugitive dust. Consequently, the Application Case construction phase is considered to capture the effects from the decommissioning of the CRL structures.

7.3.2 Geology and Hydrogeology

Measurements of radionuclide concentrations have been performed at specific areas of concern within the CRL property. This has included studies of groundwater contamination in areas impacted by groundwater plumes from WMAs at CRL. Radiological contamination in the East Swamp wetland is relevant to the NSDF Project, as this area is immediately west of the NSDF Project site. Because this wetland is potentially downgradient of parts of the NSDF Project site, characterization of the contamination present is important in defining baseline conditions. The East Swamp wetland has existing contamination associated with a shallow subsurface plume from the Chemical Pit, and a second plume from Reactor Pit 2. Cumulative effects of past and existing projects on hydrogeology have been considered through assessment of the Base Case and Application Case (see Section 5.3.2.6).

There are no RFDs expected in the CRL property (i.e., the RSA) with the exception of new/upgrades to research and development facilities, new support infrastructure, and ongoing decommissioning and environmental restoration activities (see Section 5.3). New support infrastructure and research and development facilities will be located within existing disturbed areas on the CRL property (i.e., no disturbance to Greenfield areas). As such, potential effects from these activities are not expected to spatially overlap with potential effects to geology from the NSDF Project, nor are they anticipated to have an interaction with hydrogeology. The end-state plan for the CRL site will be to return lands disturbed by site activities to a condition that is physically stable, and safe in keeping with the land use and landscape of the day. Therefore, decommissioning and environmental restoration activities are anticipated to positively affect geology and hydrogeology. Because RFDs will either have no spatial overlap (i.e., soils), no interaction (i.e., hydrogeology) or are likely to positively affect the VC (i.e., geology and hydrogeology), an RFD Case is not presented as part of this assessment. No potable water wells anticipated to be installed within the RSA during the time up to the end of the post-closure phase.

7.3.3 Surface Water Environment

Surface water sampling locations are monitored routinely throughout the Perch Creek basin. The East Swamp wetland, located in the Perch Creek basin, has existing contamination associated with a shallow subsurface plume from the Chemical Pit, and a second plume from Reactor Pit 2. Treated effluent from the WWTP will be released to an exfiltration gallery promote the exfiltration of treated water into the local groundwater regime; from here, small quantities of residual contaminants will migrate towards the East Swamp Stream. The East Swamp Stream feeds Perch Lake, which is connected to the Ottawa River through Perch Creek. Residual contaminants from the WWTP effluent will be most concentrated with the East Swamp Stream due to further dilution in downstream waterbodies (e.g., Perch Lake, Perch Creek). Because this wetland is potentially downgradient of parts of the NSDF Project site, characterization of the contamination present is important in defining baseline conditions. Cumulative effects of past and existing projects on surface water have been considered through assessment of the Base Case and Application Case.

There are no RFDs expected in the CRL property (i.e., the RSA) with the exception of new/upgrades to research and development facilities, new support infrastructure, and ongoing decommissioning and environmental restoration activities. New support infrastructure and research and development facilities will be located within existing disturbed areas on the CRL property (i.e., no disturbance to Greenfield areas). Potential effects from these activities are not expected to spatially overlap with potential effects to surface water quality from the NSDF Project, nor are they anticipated to have an interaction with hydrology. The NSDF Project will enable the remediation of contaminated lands and legacy waste management areas, and decommissioning of outdated infrastructure at the

CRL property and CNL's other business locations to support future CNL missions. The end-state plan for the CRL site will be to return lands disturbed by site activities to a condition that is physically stable, and safe in keeping with the land use and landscape of the day. Therefore, decommissioning and environmental restoration activities are anticipated to positively affect hydrology and surface water quality. Because RFDs will either have no spatial overlap (i.e., surface water quality), no interaction (i.e., hydrology) or are likely to positively affect the VC (i.e., hydrology and surface water quality), an RFD Case is not presented as part of this assessment.

7.3.4 Aquatic Biodiversity

There are no RFDs expected in the CRL property (i.e., the RSA) with the exception of new/upgrades to research and development facilities, new support infrastructure, and ongoing decommissioning and environmental restoration activities. New support infrastructure and research and development facilities will be located within existing disturbed areas on the CRL property (i.e., no disturbance to Greenfield areas). Potential effects from these activities are not expected to spatially overlap with potential effects to aquatic biodiversity from the NSDF Project. The end-state plan for the CRL site will be to return lands disturbed by site activities to a condition that is physically stable, and safe in keeping with the land use and landscape of the day. Therefore, decommissioning and environmental restoration activities are anticipated to positively affect fish and fish habitat. Because RFDs will have no spatial overlap and are likely to positively affect the fish and fish habitat, an RFD Case is not presented as part of this assessment.

7.3.5 Terrestrial Biodiversity

For terrestrial biodiversity, the RSA used as the scale at which cumulative effects to terrestrial biodiversity VCs were assessed (see Section 5.6). Regional disturbance factors (e.g., forestry and climate change) were considered if they were likely to affect vegetation communities or populations of wildlife VCs that overlap with the RSA. The assessment considered the Base Case, which represents existing conditions and characterizes effects from previous and existing developments and activities, as well as the Application Case, which represents the effects of the Base Case combined with the predicted incremental effects from the NSDF Project through all project phases for each VC. The Base Case reflects the effects of existing disturbances in the area, such as forestry, transportation, agricultural, mining, and residential and recreational development.

The VCs selected for the terrestrial biodiversity assessment were: vegetation communities, migratory birds, Canada warbler, eastern whip-poor-will, golden-winged warbler, bats, and Blanding's turtle. The assessment endpoint for terrestrial biodiversity is the maintenance of self-sustaining and ecologically effective vegetation communities or wildlife populations.

Residual effects to terrestrial VCs are primarily associated with vegetation clearing and grubbing and the associated loss or alteration of existing vegetation and topographical features; sensory disturbance from NSDF Project activities during construction and operations; and increased risk of injury/mortality on roads due to equipment and vehicle traffic. The cumulative effects from the NSDF Project and previous and existing activities and developments in the RSA on the population of terrestrial biodiversity VCs that overlap with the RSA are predicted to be not significant for all VCs, with the exception of bats and Blanding's turtle. These are discussed further below.

There are no RFDs expected in the CRL property (i.e., the RSA) with the exception of new/upgrades to research and development facilities, new support infrastructure, and ongoing decommissioning and environmental restoration activities. New support infrastructure and research and development facilities will be located within

existing disturbed areas on the CRL property (i.e., no disturbance to Greenfield areas). As such, potential effects from these activities are not expected to spatially overlap with potential effects to terrestrial biodiversity from the NSDF Project. The end-state plan for the CRL site will be to return lands disturbed by site activities to a condition that is physically stable, and safe in keeping with the land use and landscape of the day. Therefore, decommissioning and environmental restoration activities are anticipated to positively affect terrestrial biodiversity. Once existing infrastructure is removed and the CNL site is reclaimed and ceases to be frequented by large numbers of employees, the level of anthropogenic disturbance within the site will be greatly reduced, benefiting terrestrial biodiversity in the RSA. Because RFDs will have no spatial overlap and are likely to positively affect terrestrial biodiversity, an RFD Case is not presented as part of this assessment.

7.3.5.1 Bats

Populations of little brown myotis, northern myotis and tri-colored bats that overlap the terrestrial biodiversity RSA are highly sensitive to changes in survival and reproduction because white-nose syndrome has resulted in dramatic declines of these species across the eastern portions of their Canadian range, which includes the RSA. Therefore, the existing level of pressure on these bat species in the Base Case has likely already exceeded their resilience and adaptability limits and they are unlikely to be self-sustaining or ecologically effective. Consequently, the cumulative effects of existing disturbance and especially the introduced white-nose syndrome are considered significant at Base Case (i.e., even before the project is included).

The NSDF Project will contribute a small increment to this existing significant adverse cumulative effect. Importantly, because vegetation clearing will be undertaken outside of the maternity roosting season, no mortality of roosting bats is expected as a result of the NSDF Project and effects or the NSDF Project to survival and reproduction are considered neutral. In addition, the remaining availability of potential maternity roosting habitat is not likely a limiting factor in the terrestrial biodiversity RSA. Therefore, the contribution of the NSDF Project to the existing significant adverse cumulative effect to bats is predicted to be minor.

Offsetting the removal of unoccupied bat maternity roost trees is not required under the *Species At Risk Act*, however, installation of bat boxes in suitable locations in the terrestrial biodiversity RSA is recommended to mitigate the incremental contribution of the NSDF Project. Monitoring will be conducted to determine if boxes are being used.

7.3.5.2 Blanding's Turtle

The NSDF Project footprint would permanently remove 22 hectares (ha) of proposed Blanding's turtle critical habitat during construction. This upland habitat affected by the project currently has the potential to be used by Blanding's turtle for nesting, thermoregulation and summer inactivity. Females who use the area for nesting may experience a reduction in reproductive success until they find new areas within which to nest. In addition, the interruption or barrier to Blanding's turtles moving through the NSDF Project site will result in the need to travel longer distances around the site in search of nesting habitat and will increase their risk of injury or mortality on roads. The increase in traffic related to the NSDF Project and consequently the risk of road injury or mortality will be mitigated through a comprehensive road mitigation plan, however the risk of road mortality, albeit reduced still remains.

It is possible that the level of habitat fragmentation and road mortality existing on the CRL site are significantly impacting the population of Blanding's turtle in the Base Case at an unsustainable rate. Consequently, cumulative

effects from the NSDF Project and previous and existing activities and developments on the Blanding's turtle population are predicted to be significant.

The destruction of proposed critical habitat for Blanding's turtle will require a Species at Risk permit. Further studies of this population are required to determine where nesting habitats occur. In addition, a comprehensive assessment of high risk crossing locations will be completed for Blanding's turtles. Consideration will be given to the location and type of existing crossing culverts as passageways or upgrade or install new crossing structures that are conducive to Blanding's turtle safe passage under the roads.

7.3.6 Ambient Radioactivity and Ecological Health

Canadian Nuclear Laboratories reports the results of the Environmental Monitoring Program for the CRL site each year to the Canadian Nuclear Safety Commission. The Environmental Monitoring Program data is collected to verify that radiation doses to ecological receptors as a result of the operations of the CRL site remain as low as reasonably achievable. It is noted that additional future site activities may impact the baseline radioactivity prior to NSDF operations. For example, the shutdown of NRU scheduled for 2018 will reduce airborne emissions at CRL and is expected to result in lower environmental concentrations of some radiological contaminants. In addition, emissions from the B206 stack and cemented molybdenum waste storage have ceased as the facility has been shutdown (production ended in 2016).

Measurements of radionuclide concentrations have been performed at specific areas of concern within the CRL property. This has included studies of ambient radiation as well as soil, groundwater, and vegetation contamination in areas impacted by groundwater plumes from WMAs at CRL. Radiological contamination in the East Swamp wetland is relevant to the NSDF Project, as this area is immediately west of the NSDF Project site. Because this wetland is potentially downgradient of parts of the NSDF Project site, characterization of the contamination present is important in defining baseline conditions. The East Swamp wetland has existing contamination associated with a shallow subsurface plume from the Chemical Pit, and a second plume from Reactor Pit 2. The surface contamination distribution in the East Swamp has been characterized on a 5-year frequency with radiation field surveys, surface surveys, and vegetation contamination surveys performed in 2002, 2007 and 2012. Additional relevant surveying has been performed to characterize the Chemical Pit plume. Based on the 5-year frequency, surveying in East Swamp will again be conducted in 2017. Cumulative effects of past and existing projects on ecological health have been considered through assessment of the Base Case and Application Case (see Section 5.7.6).

There are no RFDs expected in the CRL property (i.e., the RSA) with the exception of new/upgrades to research and development facilities, new support infrastructure, and ongoing decommissioning and environmental restoration activities. Potential effects from these activities are not expected to spatially overlap with potential effects to ecological health from the NSDF Project. The NSDF Project will enable the remediation of contaminated lands and legacy waste management areas, and decommissioning of outdated infrastructure at the CRL property and CNL's other business locations to support future CNL missions. The end-state plan for the CRL site will be to return lands disturbed by site activities to a condition that is physically stable, and safe in keeping with the land use and landscape of the day. Therefore, decommissioning and environmental restoration activities are anticipated to positively affect ecological health. Because RFDs will have no spatial overlap and are likely to positively affect ecological health, an RFD Case is not presented as part of this assessment.

7.3.7 Human Health

Canadian Nuclear Laboratories reports the results of the Environmental Monitoring Program for the CRL site each year to the Canadian Nuclear Safety Commission. The Environmental Monitoring Program data is collected to verify that radiation doses to members of the public as a result of the operations of the CRL site remain as low as reasonably achievable. The calculated radiation dose to members of the public from CRL operations in 2015 represents the baseline radiation dose from CRL prior to the NSDF Project (i.e., Base Case). The 2015 dose assessment showed that radiation dose to the public from CRL operations was below the effective dose limit of 1 millisievert per year (mSv/yr) for members of the public. Cumulative effects of past and existing projects on human health have been considered through assessment of the Base Case and Application Case (see Section 5.8.6).

There are no RFDs expected in the CRL property (i.e., the RSA) with the exception of new/upgrades to research and development facilities, new support infrastructure, and ongoing decommissioning and environmental restoration activities. Potential effects from these activities are not expected to spatially overlap with potential effects to human health from the NSDF Project. The NSDF Project will enable the remediation of contaminated lands and legacy waste management areas, and decommissioning of outdated infrastructure at the CRL property and CNL's other business locations to support future CNL missions. The end-state plan for the CRL site will be to return lands disturbed by site activities to a condition that is physically stable, and safe in keeping with the land use and landscape of the day. Therefore, decommissioning and environmental restoration activities are anticipated to positively affect human health. Because RFDs will have no spatial overlap and are likely to positively affect human health, an RFD Case is not presented as part of this assessment.

7.3.8 Land and Resource Use

The land and resource use RSA is defined as the area within which the potential effects of the NSDF Project may interact with the effects of other existing or reasonably foreseeable projects. The land use and resource use RSA corresponds with the combined area of the terrestrial and aquatics RSAs and is defined to capture direct and indirect effects on the terrestrial and aquatic environment resulting from the Project (e.g., habitat loss, sensory disturbance for wildlife and changes to habitat from dust deposition) as these effects have the potential to result in subsequent effects on land and resource use.

There are no RFDs expected in the CRL property (i.e., the RSA) with the exception of new/upgrades to research and development facilities, new support infrastructure, and ongoing decommissioning and environmental restoration activities. New support infrastructure and research and development facilities will be located within existing disturbed areas on the CRL property (i.e., no disturbance to Greenfield areas). As such, potential effects from these activities are not expected to spatially overlap with potential effects to land and resource use from the NSDF Project. The end-state plan for the CRL site will be to return lands disturbed by site activities to a condition that is physically stable, and safe in keeping with the land use and landscape of the day. Therefore, decommissioning and environmental restoration activities are anticipated to positively affect land and resource use. Because RFDs will have no spatial overlap and are likely to positively affect land and resource use, an RFD Case is not presented as part of this assessment.

7.3.9 Socio-economics

The socio-economics assessment considered potential cumulative effects as part of the Base Case, Application Case and RFD Case. Within the socio-economic RSA, CNLs Nuclear Power Demonstration (NPD) Closure Project is anticipated to overlap temporally and spatially with the NSDF Project. Decommissioning of the NPD Project is expected to occur from 2018 to 2020 and it is anticipated that workforce and business opportunities within Town of Petawawa and City of Pembroke will overlap with those required for the NSDF Project. The CNL NPD Project is the only foreseeable project that has been identified to overlap spatially and temporally with the NSDF Project. The effects of the NPD Project were considered for their potential to affect socio-economic VCs (i.e., labour market and economic development, services and infrastructure, and housing and accommodation). The NPD Project is a decommissioning project with relatively small employment and procurement levels (i.e., 15 to 30 external contractors and $5 to $10 million in expenditure). Therefore, it was determined that there would be no additional adverse effects on these VCs as a results of the RFD Case.

8.0 SUMMARY OF SIGNIFICANCE OF RESIDUAL EFFECTS

The following assessments were completed to evaluate the biophysical and human environment effects of the Near Surface Disposal Facility (NSDF) Project and to satisfy the requirements of the review being undertaken under the *Canadian Environmental Assessment Act, 2012* (CEAA 2012):

- Section 5.2 Atmospheric Environment;
- Section 5.3 Geological and Hydrogeological Environment;
- Section 5.4 Surface Water Environment;
- Section 5.5 Aquatic Biodiversity;
- Section 5.6 Terrestrial Biodiversity;
- Section 5.7 Ambient Radioactivity and Ecological Health;
- Section 5.8 Human Health;
- Section 5.9 Land and Resource Use; and,
- Section 5.10 Socio-economic Environment.

The residual effects classification of primary pathways and the associated predicted changes in measurement indicators provide the foundation for determining the significance of incremental and cumulative effects from the NSDF Project and other existing, approved, and reasonably foreseeable developments on valued component (VC) assessment endpoints. The overall environmental assessment approach described in Section 5.1 was used for the assessment of residual effects that cannot be avoided or mitigated through the re-design or relocation of the proposed Project or through proponent commitments. Modifications in the approach (where applicable) are described in detail in the discipline assessments (Sections 5.2 through 5.10).

Table 8.0-1 summarizes the proposed environmental design features and mitigation, residual effects, and significance of effects (where applicable) for the Application Case and the Reasonably Foreseeable Development (RFD) Case (where applicable) for each of the VCs. The classification of residual adverse effects and the determination of significance are completed only for those VCs that have assessment endpoints. The intent of the environmental assessment is to predict if the NSDF Project is likely to cause a significant adverse (i.e., negative) effect on the environment or to cause public concern. Although the neutral and positive residual effects associated with the NSDF Project are reported in the relevant discipline assessments, they are not assessed for significance.

This page left intentionally blank

Table 8.0-1: Summary of Predicted Residual Effects on Valued Components and Significance – Application Case and Reasonably Foreseeable Developments Case

Discipline	Valued Component	Assessment Endpoint	Residual Effect	Project Phase the Effect Occurs in	Contributing Project Activity	Mitigation	Significance	
							Application Case	RFD Case
Atmospheric Environment	Air Quality	Performance against criteria and thresholds for protection of human health and the environment	■ Construction activities use vehicles and equipment that combust fuel and emit indicator compounds. These activities involve material handling, vehicles travelling on paved and unpaved roads, and wind erosion of stockpiles that will result in fugitive dust emissions.	Construction	■ Site preparation ■ Construction of the Engineered Containment Mound (ECM) ■ Development of surface water management structures ■ Construction of the Waste Water Treatment Plant (WWTP) and other support facilities ■ On-site road and access development	■ Implementation of Canadian Nuclear Laboratories' (CNL) Procedure for Management and Monitoring of Emissions, which includes operational control monitoring and air verification monitoring. ■ The Dust Management Plan for the NSDF Project will be developed and will include: ▪ Restricting or suspending activities if unacceptable amounts of dust are generated due to winds or other site conditions. ▪ Use of water spraying or misting techniques (e.g., water trucks) as the primary dust control method; ▪ Use of fixatives (e.g., chemical suppressant) for dust control during winter season or shutdown periods, and for use as daily/interim cover. ▪ Suspension of excavating, loading, hauling, and dumping operations when wind speeds exceed the specified criterion. ▪ Vehicles that have come into contact with contamination will be required to pass through the vehicle decontamination facility. ■ On-site vehicles and equipment engines will meet Tier 2 emission standards and be maintained in good working order. ■ Limit idling of vehicles on-site. ■ Processed leachate will not be heated within the WWTP. ■ There is active ventilation within the WWTP building and all emissions to air will be filtered prior to release.	Not Significant	Not applicable
			■ Most activity and material handling occurs during the operations phase, and pathways include: ▪ vehicles and equipment combust fuel and emit indicator compounds; ▪ material handling, vehicles travelling on paved unpaved roads, and wind erosion of stockpiles emit fugitive dust; ▪ the disposal cell cover and the WWTP emit odour.	Operations	■ Staged development of ECM disposal cells ■ On-site transportation of waste and placement of waste in the ECM ■ Progressive closure of disposal cells and installation of cover ■ Operation of the WWTP		Not Significant	Not applicable
			■ Air emissions from the decomposition of waste.	Operations and Post-closure	■ Placement of waste in the ECM	■ Installation of the final disposal cell cover will reduce release of emissions from the ECM.	Not Significant	Not applicable
	Greenhouse Gases	Comparison to provincial and national totals	■ GHG emissions from the decomposition of waste.	Operations and Post-closure	Placement of waste in the ECM	■ Installation of the final disposal cell cover will reduce release of emissions from the ECM.	Not Significant	Not applicable

Table 8.0-1: Summary of Predicted Residual Effects on Valued Components and Significance – Application Case and Reasonably Foreseeable Developments Case

Discipline	Valued Component	Assessment Endpoint	Residual Effect	Project Phase the Effect Occurs in	Contributing Project Activity	Mitigation	Significance	
							Application Case	RFD Case
Atmospheric Environment (continued)	Greenhouse Gases (continued)	Comparison to provincial and national totals	■ Most activity and material handling occurs during this stage. Vehicles and equipment combust fuel and emit GHGs. These activities involve material handling with vehicles travelling on roads. The disposal cell emits GHG emissions from the decomposition of waste. The WWTP will be fuelled by Natural Gas. Additionally, there is a loss of carbon sink as a result of the cleared land for the NSDF Project.	Construction and Operations	Construction ■ Site preparation ■ Construction of the ECM ■ Development of surface water management structures ■ Construction of the WWTP and other support facilities ■ On-site road and access development Operations ■ Staged development of disposal cells ■ On-site transportation of waste and placement of waste in the ECM ■ Progressive closure of disposal cells and installation of cover ■ Operation of the WWTP	■ Implementation of CNL's Procedure for Management and Monitoring of Emissions, which includes operational control monitoring and verification monitoring. ■ On-site vehicles and equipment engines will be maintained in good working order. ■ Limit idling of vehicles on-site.	Not Significant	Not applicable
Physical Environment	Groundwater Quantity	Intermediate component (i.e., it does not have an assessment endpoint)	■ The construction of the NSDF Project will physically alter groundwater levels and flows.	Construction through to post-closure	■ Construction of the ECM	■ The NSDF Project footprint has been designed to limit disturbance to the natural environment. ■ Discharge of treated effluent to the exfiltration gallery area will help to reduce water loss from the hydrogeological system.	Significance is not determined as VC does not have an assessment endpoint.	Not applicable
	Groundwater Quality	Intermediate component (i.e., it does not have an assessment endpoint)	■ Leakage of leachate from the ECM during the post-closure phase (i.e., after Year 2400) from liner and cover failure as a result of normal evolution can cause changes to groundwater quality.	Post-closure	■ Leakage of leachate from the ECM from normal evolution	■ The final cover system will be constructed to promote the shedding of surface water to mitigate infiltration into the mound, and minimize leachate generation. ■ The cover system design incorporates a series of shallow, trapezoidal, riprap-lined drainage channels that are designed to convey water at low velocity. ■ The perimeter road ditch will route the runoff around the ECM perimeter to minimize ponding of water into the closed ECM, erosion of the cover and underlying waste materials, destabilization of the ECM structure, and damage to access roads. ■ The ECM final grading and drainage plan also includes collection ditches along the top of the ECM berm road to collect side slope drainage.	Significance is not determined as VC does not have an assessment endpoint.	Not applicable

Table 8.0-1: Summary of Predicted Residual Effects on Valued Components and Significance – Application Case and Reasonably Foreseeable Developments Case

Discipline	Valued Component	Assessment Endpoint	Residual Effect	Project Phase the Effect Occurs in	Contributing Project Activity	Mitigation	Significance	
							Application Case	RFD Case
Surface Water Environment	Hydrology	Intermediate component (i.e., it does not have an assessment endpoint)	■ The installation of the ECM will physically alter drainage patterns, and may change downstream discharge, water levels in adjacent wetlands, and channel/bank stability.	Closure and Post-closure	■ Construction of the ECM ■ Development and operation of surface water management structures ■ Construction the WWTP and other support facilities ■ On-site road and access development	■ The final cover is designed to promote positive drainage from the NSDF Project site and reduce erosion or abrasion of the cover. ■ The final cover system will be constructed to promote the shedding of surface water to mitigate infiltration into the mound, and minimize leachate generation. ■ The cover system design incorporates a series of shallow, trapezoidal, riprap-lined drainage channels that are designed to convey water at low velocity. ■ The perimeter road ditch will route the runoff around the ECM perimeter to minimize ponding of water into the closed ECM, erosion of the cover and underlying waste materials, destabilization of the ECM structure, and damage to access roads. ■ The ECM final grading and drainage plan includes collection ditches along the top of the ECM berm road to collect side slope drainage. ■ Environmental monitoring will be completed throughout the post-closure phase for the NSDF Project to confirm that the cover is functioning as intended.	Significance is not determined as VC does not have an assessment endpoint.	Not applicable
Surface Water Environment	Surface Water Quality	Intermediate component (i.e., it does not have an assessment endpoint)	■ Discharge of treated effluent from the WWTP to the East Swamp Wetland can cause changes to downstream surface water quality.	Operations and Post-closure	■ Discharge of treated effluent	■ The strategy for wastewater treatment is based on optimizing public and environmental protection by defining an approach to wastewater treatment that uses best demonstrated available technology that is economically achievable (BDATEA), and capable of meeting regulatory requirements. ■ The treatment target for effluent is the CRL Acceptability Criteria for Routine and Non Routine Discharge of Liquids to Stormwaters. ■ Treated effluent will be sampled and confirmed that it meets treatment targets before release to East Swamp Wetland. ■ An exfiltration gallery is proposed at the discharge outlet to promote the exfiltration of treated water into the local groundwater regime. ■ Appropriate procedures to identify emergency spill occurrences and response, as well as appropriate response to non-contact surface water or leachate contamination will also be implemented as described in the Operations and Maintenance Plan and Contingency Plan.	Significance is not determined as VC does not have an assessment endpoint.	Not applicable

Table 8.0-1: Summary of Predicted Residual Effects on Valued Components and Significance – Application Case and Reasonably Foreseeable Developments Case

Discipline	Valued Component	Assessment Endpoint	Residual Effect	Project Phase the Effect Occurs in	Contributing Project Activity	Mitigation	Significance	
							Application Case	RFD Case
Surface Water Environment (continued)	Surface Water Quality (continued)	Intermediate component (i.e., it does not have an assessment endpoint) (continued)	■ Leakage of leachate from the ECM during the post-closure phase (i.e., after Year 2400) from liner and cover failure as a result of normal evolution can cause changes to downstream surface water quality.	Post-closure	■ Liner and cover failure as a result of normal evolution	■ The final cover is designed to promote positive drainage from the NSDF Project site and reduce erosion or abrasion of the cover. ■ The final cover system will be constructed to promote the shedding of surface water to mitigate infiltration into the mound, and minimize leachate generation. ■ The cover system design incorporates a series of shallow, trapezoidal, riprap-lined drainage channels that are designed to convey water at low velocity. ■ The perimeter road ditch will route the runoff around the ECM perimeter to minimize ponding of water into the closed ECM, erosion of the cover and underlying waste materials, destabilization of the ECM structure, and damage to access roads. ■ The ECM final grading and drainage plan includes collection ditches along the top of the ECM berm road to collect side slope drainage. ■ Environmental monitoring will be completed throughout the post-closure phase for the NSDF Project to confirm that the cover is functioning as intended.	Significance is not determined as VC does not have an assessment endpoint.	Not applicable
Terrestrial Biodiversity	Vegetation Communities (including wetlands)	Maintenance of self-sustaining and ecologically effective vegetation communities	■ Permanent loss of 30 ha of forested communities. ■ Permanent changes to the distribution of forested habitats; no changes to the distribution of wetlands. ■ Permanent edge effects may alter adjacent vegetation community richness.	All phases	■ Vegetation clearing and grubbing	■ The NSDF Project footprint has been designed to avoid wetlands and limit disturbance to the natural environment to the extent feasible. For example, as the ECM is developed sequentially, undeveloped cells may be prepared and used as stockpile areas to store overburden soils to be used during construction or for daily/interim cover stockpiles. This approach reduces the required area for the laydown and stockpile of materials. ■ A 30 m buffer is established along all identified wetlands near the NSDF site. ■ A 5 m tree-line buffer is established from all property lines on the NSDF site in order to limit disturbance to vegetation and large tree roots at the tree-line.	Not Significant	Not applicable

Table 8.0-1: Summary of Predicted Residual Effects on Valued Components and Significance – Application Case and Reasonably Foreseeable Developments Case

Discipline	Valued Component	Assessment Endpoint	Residual Effect	Project Phase the Effect Occurs in	Contributing Project Activity	Mitigation	Significance	
							Application Case	RFD Case
Terrestrial Biodiversity (continued)	Canada Warbler	Maintenance of self-sustaining and ecologically effective populations	■ Permanent loss of 25 ha of suitable habitat ■ Possible long-term avoidance in the LSA from sensory disturbance ■ Permanent small change in movement in the LSA ■ Permanent small reduction in carrying capacity	All phases	■ Vegetation clearing and grubbing ■ Mobilization of equipment ■ Hauling of materials ■ Blasting	■ The NSDF Project footprint has been designed to avoid wetlands and limit disturbance to the natural environment to the extent feasible. For example, as the ECM is developed sequentially, undeveloped cells may be prepared and used as stockpile areas to store overburden soils to be used during construction or for daily/interim cover stockpiles. This approach reduces the required area for the laydown and stockpile of materials. ■ A 30 m buffer is established along all identified wetlands near the NSDF site. ■ A 5 m tree-line buffer is established from all property lines on the NSDF site in order to limit disturbance to vegetation and large tree roots at the tree-line. ■ Avoid conducting the activities with highest levels of noise and habitat disturbance during most sensitive life history phase (i.e., breeding and nesting for birds, maternity roosting for bats) by conducting vegetation clearing and grubbing before April 8, or after August 31 to avoid effects on nesting birds.	Not Significant	Not applicable
	Eastern Whip-poor-will	Maintenance of self-sustaining and ecologically effective populations	■ Permanent loss of 1 ha of suitable habitat ■ Possible long-term avoidance in the LSA from sensory disturbance ■ Permanent small change in movement in the LSA ■ Permanent small reduction in carrying capacity	All phases	■ Vegetation clearing and grubbing ■ Mobilization of equipment ■ Hauling of materials ■ Blasting	■ The NSDF Project footprint has been designed to avoid wetlands and limit disturbance to the natural environment to the extent feasible. For example, as the ECM is developed sequentially, undeveloped cells may be prepared and used as stockpile areas to store overburden soils to be used during construction or for daily/interim cover stockpiles. This approach reduces the required area for the laydown and stockpile of materials. ■ A 30 m buffer is established along all identified wetlands near the NSDF site. ■ A 5 m tree-line buffer is established from all property lines on the NSDF site in order to limit disturbance to vegetation and large tree roots at the tree-line. ■ Avoid conducting the activities with highest levels of noise and habitat disturbance during most sensitive life history phase (i.e., breeding and nesting for birds, maternity roosting for bats) by conducting vegetation clearing and grubbing before April 8, or after August 31 to avoid effects on nesting birds.	Not Significant	Not applicable

Table 8.0-1: Summary of Predicted Residual Effects on Valued Components and Significance – Application Case and Reasonably Foreseeable Developments Case

Discipline	Valued Component	Assessment Endpoint	Residual Effect	Project Phase the Effect Occurs in	Contributing Project Activity	Mitigation	Significance	
							Application Case	RFD Case
Terrestrial Biodiversity (continued)	Golden-winged Warbler	Maintenance of self-sustaining and ecologically effective populations	■ Permanent loss of 24 ha of suitable habitat ■ Possible long-term avoidance in the LSA from sensory disturbance ■ Permanent small change in movement in the LSA ■ Permanent small reduction in carrying capacity	All phases	■ Vegetation clearing and grubbing ■ Mobilization of equipment ■ Hauling of materials ■ Blasting	■ The NSDF Project footprint has been designed to avoid wetlands and limit disturbance to the natural environment to the extent feasible. For example, as the ECM is developed sequentially, undeveloped cells may be prepared and used as stockpile areas to store overburden soils to be used during construction or for daily/interim cover stockpiles. This approach reduces the required area for the laydown and stockpile of materials. ■ A 30 m buffer is established along all identified wetlands near the NSDF site. ■ A 5 m tree-line buffer is established from all property lines on the NSDF site in order to limit disturbance to vegetation and large tree roots at the tree-line. ■ Avoid conducting the activities with highest levels of noise and habitat disturbance during most sensitive life history phase (i.e., breeding and nesting for birds, maternity roosting for bats) by conducting vegetation clearing and grubbing before April 8, or after August 31 to avoid effects on nesting birds.	Not Significant	Not applicable
	Bats	Maintenance of self-sustaining and ecologically effective populations	■ Permanent loss of 25 ha of high quality potential maternity roost habitat ■ Potential long-term avoidance of adjacent maternity roosting habitat in the LSA from sensory disturbance ■ Permanent negligible change in movement corridors between maternity roosting habitat patches	All phases	■ Vegetation clearing and grubbing ■ Mobilization of equipment ■ Hauling of materials ■ Blasting	■ The NSDF Project footprint has been designed to avoid wetlands and limit disturbance to the natural environment to the extent feasible. For example, as the ECM is developed sequentially, undeveloped cells may be prepared and used as stockpile areas to store overburden soils to be used during construction or for daily/interim cover stockpiles. This approach reduces the required area for the laydown and stockpile of materials. ■ A 30 m buffer is established along all identified wetlands near the NSDF site. ■ A 5 m tree-line buffer is established from all property lines on the NSDF site in order to limit disturbance to vegetation and large tree roots at the tree-line. ■ Avoid conducting the activities with highest levels of noise and habitat disturbance during most sensitive life history phase (i.e., breeding and nesting for birds, maternity roosting for bats) by conducting vegetation clearing and grubbing before April 8, or after August 31 to avoid effects on bat maternity roosts.	Significant	Not applicable

Table 8.0-1: Summary of Predicted Residual Effects on Valued Components and Significance – Application Case and Reasonably Foreseeable Developments Case

Discipline	Valued Component	Assessment Endpoint	Residual Effect	Project Phase the Effect Occurs in	Contributing Project Activity	Mitigation	Significance	
							Application Case	RFD Case
Terrestrial Biodiversity (continued)	Blanding's Turtle	Maintenance of self-sustaining and ecologically effective populations	■ Permanent loss of 22 ha of proposed critical habitat ■ Permanent change in movement corridors between habitat patches ■ Long-term increased risk of injury/mortality on roads from increased traffic ■ Permanent increased risk of mortality from changes to movement patterns	All phases	■ Vegetation clearing and grubbing ■ Mobilization of equipment ■ Hauling of materials ■ Installation and maintenance of perimeter fencing	■ The NSDF Project footprint has been designed to avoid wetlands and limit disturbance to the natural environment to the extent feasible. For example, as the ECM is developed sequentially, undeveloped cells may be prepared and used as stockpile areas to store overburden soils to be used during construction or for daily/interim cover stockpiles. This approach reduces the required area for the laydown and stockpile of materials. ■ A 30 m buffer is established along all identified wetlands near the NSDF site. ■ A 5 m tree-line buffer is established from all property lines on the NSDF site in order to limit disturbance to vegetation and large tree roots at the tree-line ■ Avoid conducting the activities with highest levels of noise and habitat disturbance during most sensitive life history phase (i.e., breeding and nesting for birds, maternity roosting for bats) by conducting vegetation clearing and grubbing before April 8, or after August 31 to avoid effects on nesting birds, bat maternity roosts and the active Blanding's turtle season. ■ Install reptile exclusion fencing around perimeter of the NSDF Project site prior to initiating activities during the construction phase or prior to the active Blanding's turtle season (i.e., prior to April). ■ Repair damaged or ineffective fencing and signage. ■ Develop and implement a road mitigation plan for roads in the LSA (East Mattawa Road, Dump Road, PAB Road and Plant Road) including the location and design of passages for Blanding's turtles under roads and the extent of funnel fencing to direct individuals to the safe crossing structures. ■ Drivers have standard safety training and are provided with environmental awareness training. ■ Enforce existing CNL property speed limits on access roads. ■ Post signs warning drivers of high use wildlife areas and reduce speed limits in these areas.	Significant	Not applicable

Table 8.0-1: Summary of Predicted Residual Effects on Valued Components and Significance – Application Case and Reasonably Foreseeable Developments Case

Discipline	Valued Component	Assessment Endpoint	Residual Effect	Project Phase the Effect Occurs in	Contributing Project Activity	Mitigation	Significance	
							Application Case	RFD Case
Terrestrial Biodiversity (continued)						■ Employees in vehicles encountering wildlife of concern (e.g., Blanding's turtle) on roads are required to communicate the presence of wildlife on the roads to other employees working in the area and to CNL's Environmental Staff. ■ The existing CNL Employee Education Program will be adapted to the NSDF Project prior to construction. All employees and contractors will be trained on the identification and safe handling of Blanding's turtle in order to help the turtle across the road. ■ As per CNL's Management of Land, Habitat, and Wildlife Procedure, dead or wounded animals on roads must be reported to the safety department. ■ Wildlife collisions with vehicles will be monitored, which provides feedback for adaptive management.		
Socio-economics	Labor Market	Continuation of employment opportunities and income generation	■ Direct and indirect employment requirements may affect employment and income with the local and regional study areas	Construction	■ Employment of personnel, procurement of goods and services, and expenditures from the NSDF Project	■ CNL employment opportunities that may arise due to project activities will be posted on the www.cnl.ca website.	Positive residual effect therefore, significance is not determined	Positive residual effect therefore, significance is not determined
	Economic Development	Continuation of business and economic development	■ The NSDF Project may provide contracting and supplier opportunities to local and regional businesses	Construction	■ Employment of personnel, procurement of goods and services, and expenditures from the NSDF Project	■ The NSDF Projects will competitively procure material and services from local and regional communities.	Positive Residual Effect therefore, significance is not determined	Positive Residual Effect therefore, significance is not determined
Socio-economics (continued)	Housing and Accommodations	Maintenance of commercial accommodation availability	■ The NSDF Project could increase pressure on commercial accommodations	Construction	■ Employment of personnel, use of services and infrastructure for NSDF Project	■ None	Not significant	Not significant
	Services and Infrastructure	Maintenance of community services and infrastructure availability and access	■ Increased road degradation due to increased traffic volume from the transportation of workers, supplies, and equipment.	Construction	■ Employment of personnel, use of services and infrastructure for NSDF Project	■ Hauling for transportation of site preparation and construction equipment and construction materials on Highway 17 will be scheduled to reduce traffic volumes.	Not significant	Not significant
			■ Changes in demand for community services (health, education, protective and emergency services) with respect to the capacity of LSA services to meet the demand	All Project Phases	■ Employment of personnel, use of services and infrastructure for NSDF Project	■ Continued implementation and maintenance of compliance with all applicable health and safety standards and CNL's existing environmental, safety and security programs	Not significant	Not significant

ha = hectare; m = metre

9.0 ASSESSMENT OF EFFECTS OF THE ENVIRONMENT ON THE PROJECT

This section of the Environmental Impact Statement (EIS) discusses the effects of the environment on the Near Surface Disposal Facility (NSDF) Project, in a manner consistent with Section 2(1)(c) of the *Canadian Environmental Assessment Act, 2012* (CEAA 2012), which defines "environmental effects," in part, as "any change to the Project that may be caused by the environment, whether any such change or effect occurs within or outside Canada." Accordingly, this section focuses on the effects of natural hazards (i.e., extreme weather events, forest fires, and seismic events) and climate change on the NSDF Project. It summarizes the risks associated with each kind of environmental change, along with environmental design features, management practices, and other mitigation to reduce the risks. Malfunction and accident scenarios, not caused by natural hazards, are identified in Section 6.0 Malfunctions and Accidents, including the estimated likelihoods and consequences to the environment and public and worker safety. Additional information on the mitigation actions is reported elsewhere in the EIS, as referenced.

9.1 Extreme Weather Events

Weather events can produce extreme conditions affecting the performance of facilities and management systems. These events include extreme temperature fluctuations, thunderstorms, flooding, and tornadoes. In this section, potential effects from extreme weather events and the associated mitigation to be implemented, are described. Potential effects from shifts in the frequency and/or intensity of extreme weather events due to climate change are discussed in Section 9.4 Climate Change.

9.1.1 Temperature Fluctuations

Temperature fluctuations and the effects of freeze-thaw cycles are considered in the design of the engineered containment mound (ECM) base and cover. There are multiple components of the base and cover linings systems, including a high-density polyethylene (HDPE) geomembrane liner, geosynthetic clay liner, compacted clay liner, and final granular/soil cover; these lining systems are expected to provide an effective service life of approximately 500 years.

Natural freeze-thaw cycles could damage the linings of the ECM cover, leading to water infiltration into the waste. The NSDF Project has been designed to include a layer of clean fill on the floor of the ECM of sufficient thickness to prevent freezing of the basal liner systems prior to waste placement. Placement of similar frost protection fill on the perimeter sideslopes of the ECM is not practical and would be susceptible to erosion given that parts of the slopes will remain exposed for several years prior to buttressing with waste fill. Hence, the sideslope lining system will be subjected to freeze-thaw action. A freeze thaw assessment concluded that the sideslope HDPE geomembrane liner component of the sideslope lining system will not be adversely affected by freeze thaw cycles, whereas the geosynthetic and compacted clay liner components of the sideslope lining system could undergo an increase in hydraulic conductivity prior to placement of the wastes on the sideslopes. However, after placement of the waste, the clay liners will consolidate under the weight of the waste healing the voids caused by freezing such that the potential increase in hydraulic conductivity would be negligible for the geosynthetic clay liner and up to a factor of 2 for the compacted clay liner. The final cover system will be installed to its full thickness progressively as areas of the ECM reach the final waste contours. The final cover system design has 1.75 m of granular/soil materials above the lining system, which is sufficient to prevent freezing of the final cover liner components.

Extreme temperature fluctuations could also affect the successful establishment of vegetation used in reclamation of the site. For example, the vegetated top of the final cover system will be designed for withstanding erosion and gully initiations. The vegetation for the final cover will be limited to grass species that are maintenance-free and drought-resistant. Trees will not be allowed to establish on the final cover as they may cause considerable damage to the topsoil and soil cover layers, as well as expose the intrusion barrier if uprooted due to heavy winds (Section 3.10.4.1.5 Vegetative Cover/Erosion Protection Component of Cover System). Vegetation will be established and maintained. Bare or eroded areas will be rolled, regraded, replanted, and remulched in the same way as in the original installation to produce a uniformly-smooth grassed surface. Treatments will be applied as required to keep grass and soil free of pests and pathogens or disease (Section 3.10.4.1.5 Vegetative Cover/ Erosion Protection Component of Cover System).

9.1.2 Extreme Rainfall Events, Snowmelts and Flooding

Extreme rainfall and snowmelt events and the potential for flooding is considered in the design of the surface water management systems, berms, and the final cover for the ECM. The NSDF Project design shall comply with all relevant federal and provincial regulations, guidelines, acts, standards, and codes, including standard industry practice.

The strategy for wastewater treatment (Sections 3.5.3 Wastewater Treatment Plant [Construction Phase] and 3.6.2 Wastewater Treatment Plant [Operations Phase]) is based on optimizing public and environment protection by defining an approach to wastewater treatment that uses best demonstrated available technology that is economically achievable, and is capable of meeting or exceeding regulatory requirements. Another important hydraulic design consideration is the maximum wastewater flow rate that must be received and processed by the Waste Water Treatment Plant (WWTP). The maximum hydraulic flow rate was determined by evaluating the expected contact stormwater volume that would be produced during back-to-back 100-year, 24-hour storm events. Under these conditions, it is expected that 2,820 cubic metres (m^3) of contact stormwater would be produced, and that this contact stormwater would be removed from the ECM at a maximum rate of 59 cubic metres per hour (m^3/hour). This was selected as a worst-case design condition for determining the required volume of wastewater equalization.

The surface water management ponds are designed to address erosion and sediment control concerns during construction by providing interim sediment control and by providing water quality/quantity controls during operations, closure, and post-closure. The current surface water management pond footprints reflect the overall storage required to control post-closure flows to predevelopment levels for the 2-year through to 100-year rainfall events at the site (Section 3.7.1 Surface Water Management Ponds). This volume also contains the storage required for sediment control during construction and water quality control during operations. The current footprints typically assume a maximum 100-year operating water level at a 3 m depth with 1 m of freeboard that includes allowance for climate change impacts and rain on snowmelt. Major system (i.e., 100-year) flow routes follow the road system and ditches to the relevant surface water management ponds. The probable maximum precipitation (PMP) flow generally follows the major system route using the roadway, related ditches and adjacent lands. The PMP flow will exceed the surface water management ponds attenuation capacity, but is adequately conveyed by inlet and emergency outlet structures adjacent to the surface water management ponds (Section 3.7.1 Surface Water Management Ponds).

Severe rainstorms or snowmelts could also affect roads and cause failure of natural or engineered slopes (e.g., berms). All roadways, including the perimeter road, have ditches that convey not only roadway drainage, but drainage from adjacent lands, to the surface water management ponds. These have been designed to convey the 25-year post-development peak design flow (Section 3.7.2 Drainage Ditches and Swales). Annual maintenance activities will identify any erosion problems. In addition, a maintenance review will be completed after major storm events and after the annual spring melt to confirm there are no major erosion issues. Where drainage crosses roadways, culverts are sized to convey the 25-year design event without road overtopping. A box storm sewer has been sized to convey the 100-year flow to Surface Water Management Pond 1, adjacent to the access road due to constraints imposed by property and roadway limits that preclude the use of a ditch (Section 3.7.3 Culverts and Sewers). Annual maintenance activities will identify any erosion or blockage problems. In addition, a maintenance review will be completed after major storm events and after the annual spring melt to confirm there are no major erosion or blockage issues at the culvert and sewer inlet or outlet.

Designed berms consist of three main geotechnical elements, or layers, each contributing to the soundness and integrity of the berm itself and the whole ECM (Section 3.5.2.6 Berms). The inside face of the berm will be covered with the various liner system layers, while the outer face will be covered with the intrusion barrier rockfill over geomembrane, geotextile cushion and geogrid. The top of the berm is covered with various layers of granular “A” material, geomembrane and geotextile cushion with the top layer granular A becoming the top of berm roadway.

Extreme rainfall and snowmelt events could also lead to soil erosion on the ECM cover. As part of the closure phase, a final cover system will be installed on the ECM. The final cover is designed to limit water infiltration, to direct infiltration and surface water runoff away from the ECM waste emplacement area, and to resist degradation by surface geologic processes and biotic activity (e.g., prevent burrowing of animals) and inadvertent intruder attempts to access or excavate into the wastes waste cell (Section 3.10.4 Final Cover Placement for the Engineered Containment Mound). A series of drainage control features will be installed in conjunction with placement of final cover over the ECM. The finished surface of the ECM is elevated from the surrounding terrain, which limits the quantity of surface water entering the ECM from areas outside the extent of the ECM. The topographical slopes within the ECM footprint are sufficient to promote drainage, and by lining the ECM surface water collection ditches and stilling basins with rip rap and other erosion control measures, sediment transport and erosion will be minimized (Section 3.10.4 Final Cover Placement for the Engineered Containment Mound). Construction, operation, and closure activities of the ECM are designed to provide a stabilized waste array with the purpose of minimizing settlement, and water infiltration. In addition, the low point of the ECM has an elevation of approximately 160 metres above sea level (masl), while the 100-year flood elevation for the portion of the Ottawa River adjacent to the CRL property is 155 masl. Therefore, the ECM is above the Ottawa River flood level.

Heavy downpours and runoff could increase the probability of a vehicle accident, as a result of reduced visibility and poor road conditions. These concerns are already addressed by procedures in place at site, including reduced traffic speeds, increased following distance, addressing road conditions (e.g., adding aggregate) as quickly as possible and, if necessary, issuing stop-work orders.

9.1.3 Heavy Snowfall

Severe snowstorms are primarily a concern related to worker safety, performance of facilities, and loss of production, and are already encompassed by CNL's Emergency Preparedness Program. Severe snowstorms could cause failure of engineered slopes (e.g., berms) for the ECM. As discussed in Section 9.1.2 (Extreme Rainfall Events, Snowmelts and Flooding), designed berms consist of three main geotechnical elements, or layers, each contributing to the soundness and integrity of the berm itself and the whole ECM (Section 3.5.2.6 Berms). In addition, a slope stability analysis was completed to provide the information needed to support the design of the base slopes, sidewalls, and side slopes of the ECM.

Severe snowstorms could affect vehicle operation at the site because of reduced traction and visibility and increase the probability of vehicle accidents. Safety procedures are in place to address worker safety including reduced traffic speeds, increased following-distances, addressing road conditions (e.g., snow removal, sanding) as quickly as possible, and if necessary issuing work-stop-orders.

Weather uncertainties have been accounted for, and risks associated with severe snowstorms and snow loadings to facilities are managed through design criteria for the NSDF Project. For example, requirements for surface water management systems include considerations for both climate change, as well as accounting for at least 1 m of snowfall accumulation on the ground in advance of all design storm events. In addition, building structures at the CRL main campus are designed according to the relevant requirements regarding withstanding large accumulations of snow, such as Part 4 of the National Building Code of Canada (NBCC) 2015 (NRCC 2015). Infrastructure and facilities required to support the NSDF Project will be built to meet or exceed this code. Furthermore, the infrastructure and facilities design shall comply with all relevant federal and provincial regulations, guidelines, acts, standards, and codes, including standard industry practice. Consequences of potential heavy snowfalls, such as a power outage, are also encompassed by CNL's Emergency Preparedness Program.

9.1.4 High Winds

High winds can occur either on a large scale from extra-tropical storms or low pressure systems and fronts or on a small scale, from thunderstorms, or the local geography. High winds generally fall into three categories:

- tornadoes;
- extra-tropical storms (hurricanes); and,
- thunderstorm winds.

Only tornadoes and thunderstorms are relevant to the NSDF Project site; hurricanes do not impact locations that are more than a few hundred kilometres from the ocean. Tornadoes are recognized as a hazard to the facilities on the CRL property, including the NSDF Project. Tornadoes are intense rotary storms of small diameter, the vortex is usually visible as a funnel cloud, and they are associated with thunderstorms. The frequency for a tornado strike on the property is estimated to be 5.4×10^{-5} per year and a return period of 2×10^{5} years (Cheng et al. 2013). The CRL Site Characteristics Report (CNL 2013a) provides a similar analysis of the CRL location with respect to tornado frequency and concludes the CRL site exists in a geographical area that could reasonably expect a 10^{-5}-per year tornado strike. The maximum wind speed for a tornado event of this caliber is 225 kilometres (km) per hour. There is concern that climate change will increase the frequency and severity of summer storms, including tornadoes, hail storms, and lightning events (Peterson et al. 2008). These summer storms are encompassed by CNL's Emergency Preparedness Program, including extreme storms.

High winds, atmospheric pressure changes, and wind-induced projectiles have the potential to cause structural damage and/or failure of infrastructure. In 2005, the 1995 NBCC (NBCC 2005) was updated to include provisions so that basic structural resilience under low-end tornadic loads in areas of Canada defined as "tornado prone," and Environment Canada has recently compiled an updated 30-year national tornado database (Cheng et al. 2013).

Severe winds or tornadoes are primarily a concern related to worker safety, performance of facilities, and loss of production, and are already encompassed by CNL's Emergency Preparedness Program. The risks associated with severe winds or tornadoes are managed through design criteria and management practices described above. Facilities are designed according to the appropriate codes, such as the NBCC 2015. Consequences of potential tornadoes, such as a power outage, are encompassed by CNL's Emergency Preparedness Program.

High winds during operations have the potential to cause increased dust. As described in Section 3.6.1.2.6, dust control will be conducted to support waste placement operations in accordance with the Dust Management Plan during loading, transportation, placement and compaction operations. Work areas that have the potential for generating dust will require dust suppression techniques and monitoring. The primary dust control method will include water spraying or misting techniques (e.g., water trucks).

High winds could also cause soil erosion on the ECM cover, leading to water infiltration into the waste. In addition to the mitigation described in Section 9.1.2 Extreme Rainfall Events, Snowmelts and Flooding, the final cover will be vegetated to enhance evapo-transpiration and reduce the potential for soil erosion from wind and water. The vegetation will be limited to grass species that are maintenance free and drought resistant. Trees will not be allowed to establish on the final cover as they may cause considerable damage to the topsoil and soil cover layers, as well as expose the intrusion barrier if uprooted due to heavy winds (Section 3.10.4.1.5 Vegetative Cover/ Erosion Protection Component of Cover System). As described in Section 9.1.1 Temperature Fluctuations,

vegetation will be established and maintained by watering, fertilizing, weeding, mowing, trimming, dethatching, core aerating, replanting, and performing other operations as required to establish healthy, viable grassy vegetation. Bare or eroded areas will be rolled, regraded, replanted, and remulched in the same way as in the original installation to produce a uniformly smooth grassed surface. Treatments will be applied as required to keep grass and soil free of pests and pathogens or disease (Section 3.10.4.1.5 Vegetative Cover/Erosion Protection Component of Cover System).

A soil loss/erosion calculation was completed for the proposed ECM final cover system. The Revised Universal Soil Loss Equation for Application in Canada method was used in the calculation. The results show that the average soil loss for the final ECM cover system is estimated at 0.21 tonnes per hectare per year and 1.12 tonnes per hectare per year, for the vegetated top slope, and vegetated upper side slope portions of the final cover system (Section 3.10.4.1.6 Final Cover Resistance to Long-Term Erosion). Both of these calculated soil loss amounts are lower than the maximum annual allowable soil loss of 5.0 tons per acre per year.

9.2 Forest Fires

At the NSDF Project site boundary there is a neighbouring forested area, representing a potential fire hazard. Having an effective response to fires is facilitated through CNL's Emergency Preparedness Program (Section 3.13.2.5 Emergency Preparedness Program) and the Fire Protection Program (Section 3.13.2.9 Fire Protection Program). The risks associated with wildfires would therefore continue to be managed through existing procedures and design criteria. The probability of such an event has been assessed as very low, however, a fire buffer zone (5-m minimum) between forest stands and equipment will be established to further reduce the probability of a neighbouring forest fire impacting operations. In the event of a forest fire, the CRL Fire Department provides firefighting capacity 24 hours a day, 7 days a week, and firefighting procedures are in place and are backed up by CNL's Emergency Preparedness Program.

Design of infrastructure incorporates fire protection as appropriate in accordance with the NBCC 2015 (NRCC 2015). The Fire Protection Program is dedicated to the delivery of a compliant Fire Protection Program that will provide the highest level of fire and life safety to all CNL employees and facilities. The objectives of the Fire Protection Program include preventing fire losses, providing responsible fire protection management, demonstrating compliance to applicable fire protection codes and standards, and providing reliable facilities from a fire protection perspective. The Fire Protection Program provides services including developing fire prevention processes and conducting fire safety inspections. Fire hazard analyses, code compliance reviews and fire protection screenings are also conducted as part of the program. Consequences of a fire, such as a power outage, are encompassed by CNL's Emergency Preparedness Program.

In addition, as part of the Performance Assessment for the NSDF Project (CNL 2017), an assessment of the consequences of a fire at the NSDF Project site, caused by a forest fire, lightning strike or other means, was completed. A scenario was developed to evaluate the effects of 500 packages of radiological waste burning in a temporary staging area for 1 hour. The results of this assessment are summarized in Section 6.4.4.2. The evaluation concludes radiological doses to workers and member of the public are below safety criteria and meet safety objectives for the NSDF Project.

9.3 Seismic Events

Major earthquakes (i.e., seismic events) are related to movements at tectonic plate boundaries. The CNL property is located in the Ottawa-Bonnechere Graben geologic feature and adjacent to the Western Quebec Seismic Zone. This region of the country has continued to experience minor to moderate seismic activity, and within this zone, several earthquakes were documented. These include the following:

- Timiskaming, Quebec earthquake of 1935 (6.2 on the Richter Scale and epicentre over 100 kilometres [km] away);
- Cornwall, Ontario earthquake of 1944 (5.6 on the Richter Scale and epicentre over 200 km away); and,
- Val-des-Bois, Quebec earthquake of 2010 (5.0 on the Richter Scale and epicentre over 137 km away).

Most recently, an earthquake with a magnitude of 3.7 on the Richter Scale occurred on October 15, 2015 approximately 40 km from the NSDF Project site, and an earthquake with a magnitude of 3.5 occurred on May 14, 2016 approximately 10 km from the NSDF Project site, 6 km north of Petawawa, Ontario.

Should a seismic event occur at or near the NSDF Project site, this could lead to a rupture of soil material beneath the ECM and potentially result in a failure of the engineered berms and cover, resulting in damage to ECM liners and the leachate collection system. This could result in the exposure of radioactive waste at surface and leachate to flow into the groundwater without treatment.

To support the design of the NSDF Project, a Probabilistic Seismic Hazard Assessment (PSHA) was prepared, which outlines the site-specific seismic conditions and discusses applicable seismic design criteria (AECOM 2016b). To characterize the seismic hazard, the peak horizontal ground acceleration at the site is determined using seismic information from the seismic hazard maps developed for the NBCC in 2015 (NRCC 2015). The peak ground acceleration at the NSDF Project site is comparable to typical high seismic zones in North America.

The NSDF Project facilities, including the final cover design and infrastructure, are designed to meet safety factors and earthquake loading requirements, as outlined in the following design guides:

- National Building Code of Canada Seismic Design Parameters (NBCC 2015); and,
- Design for Earthquakes (Seismic Qualifications at CRL) (120-508120-OI-029).

According to the NBCC (NRCC 2015), the design ground acceleration for structures (earthquake) is associated with a 2% probability of exceedance in 50 years (2,475-year frequency of occurrence). However, the design basis earthquake associated with the 0.5% probability of exceedance in 50 years (10,000-year frequency of occurrence) as defined by CSA Standard N289.4-12 was used for the seismic design of the ECM.

An analysis of liquefaction potential has been conducted and mitigation measures will be implemented into the design of the ECM. Based on the conclusions of a seismic analysis completed on the NSDF Project design, the ECM is expected to remain functional under the 10,000-year design seismic event scenario (AECOM 2016c). During operations through the post-closure institutional control phases of the NSDF Project, the consequences of any damage to the engineered berms or the ECM cover from a beyond design earthquake would be mitigated as required. Consequences to the facility, such as a power outage, are encompassed by CNL's existing Emergency Preparedness Program.

A limiting assumption about the potential for water infiltration into the waste, following a beyond design earthquake, is that leachate is unimpeded by the multilayered cover across the whole surface of the ECM. This assumption is consistent with infiltration rates assumed for the post-closure Normal Evolution scenarios, considered in Section 5.7 Radioactivity and Section 5.8 Human Health. Therefore, potential consequences of leachate from exposed waste discharging into the groundwater are already evaluated based on the bounding assumptions used for the Normal Evolution scenarios. Furthermore, the acute human intrusion scenario discussed in Section 6.0 Malfunctions and Accidents considers consequences resulting from damage to the integrity of the ECM and exposure to waste material. Given that consequences from these bounding scenarios do not exceed the Safety Criteria, it can be concluded that damage to the structural integrity of the ECM from a seismic event after the end of Institutional Control would meet the Safety Criteria for the NSDF Project (CNL 2017).

9.4 Climate Change

Changes in the global and regional climate could affect the NSDF Project during the 50-year operations phase and beyond into the long-term post-closure phase (the design life of the ECM is 500 years). The Canadian Nuclear Safety Commission (CNSC) requires that effects assessments take into account any potential effects of climate change on a project, including an assessment of whether the project might be sensitive to changes in climate condition during its life span (CNSC 2016). As such, an effects assessment of climate change was completed that follows the guidance provided by the Federal-Provincial-Territorial Committee on Climate Change and Environmental Assessment (FPTCCCEA). This general guidance document is for practitioners incorporating climate change issues into an environmental assessment (FPTCCCEA 2003).

9.4.1 Global Climate Change Trends

The world's climate is changing as a result of a combination of natural and anthropogenic factors, and that the changes over the twentieth century can largely be attributed to human activities (AMAP 2011, IPCC 2007, NRCAN 2011). Human activities affect climate by changing the land surface and altering the composition of the atmosphere. A 100-year warming trend in surface air temperature of 0.85 degrees Celsius (°C) was observed over the period from 1880 to 2012 (IPCC 2013). Over the Canadian landmass the annual average surface air temperature warmed by 1.5°C from 1950 to 2010 (Vincent et al. 2012), and that for 2011 and 2012 surface air temperatures were 1.5°C and 1.9°C, respectively, warmer than the reference period from 1961 to 1990 (Environment Canada 2012). Also, Canada has generally become wetter in recent decades with an increase in annual precipitation of about 16% over the period from 1950 to 2010 (Mekis and Vincent 2011). Even if considerable measures to reduce greenhouse gas emissions are introduced today, it is predicted that climate change will continue to have an environmental effect for centuries. It is recognized that these effects will not occur uniformly across the country, but will vary regionally (NRCAN 2004).

Climate change projections are provided by mathematical models based on the physical laws governing the behaviour of the climate. Climate change scenarios, as summarized by the Intergovernmental Panel on Climate Change (IPCC), predict that mean global temperatures are likely to increase by 1.1°C to 5.4°C for the period of 2090 to 2099 as compared to the reference period from 1980 to 1999. The IPCC is generally considered to be the definitive source of information related to past and future climate change, as well as climate science.

It is predicted that the North, and southern and central Prairies of Canada will experience more of a warming than other regions (NRCAN 2004). This warming is expected to vary on a seasonal basis, being greater in the winter than the other seasons, and nights warming more than days. As warm air can hold more moisture, changes in precipitation patterns and shifts in the frequency and intensity of extreme climate events are expected to accompany this warming (NRCAN 2004). Mean results for Canada show that even under lowered emission scenarios, summer and winter temperatures by the middle of the century are anticipated to warm by about 1.5°C to 2.5°C and 3°C to 7°C, respectively (NRCAN 2014).

9.4.2 Current and Future Climate Change Trends

9.4.2.1 Current Climate Trends

The current climate is based on available long-term daily meteorological observations from a climate station near the NSDF Project footprint. In general, the current climate normals and trends indicate a current climate that has likely become warmer and wetter over time. The analysis of climate station data shows that temperatures are increasing, with the exception of spring, and the total seasonal precipitation show increasing trends except for winter and spring, which show a decreasing trend (Appendix 9.0-1).

An analysis of the Petawawa Hoffman climate station data was completed illustrating:

- total annual precipitation is increasing, however, the trend was not statistically significant;
- summer total precipitation is increasing;
- the number of days with more than 20 centimetres (cm) of rainfall is increasing;
- average annual temperature is increasing;
- average annual summer temperature is increasing;
- average annual fall temperature is increasing; and,
- the number of periods (greater than 3 days) with minimal temperatures below 15°C are decreasing.

9.4.2.2 Future Climate Conditions

Future climate projections were derived using General Circulation Models (GCM) for two time periods, the Mid Term representing the second half of the operations phase (2041 through 2070) and the Far Term representing the closure phase and beginning of the post-closure phase (2070 through 2100) (Appendix 9.0-1 Climate Change). Climate projections were also considered for the Long Term (2100 through 3000) using publicly available literature (Appendix 9.0-1 Climate Change).

The model projected means for the Mid Term and Far Term are greater than the observed climate normals for both temperature and precipitation (Appendix 9.0-1 Climate Change; Tables 9.4.2-1 and 9.4.2-2). On a month-to-month basis, the projections indicate a future that is likely warmer and wetter than currently observed. The change in temperature normal between the currently observed and projected monthly periods is more pronounced than the monthly projected changes in precipitation. The projected changes in monthly temperature appear reasonably uniform over the year, while the fall and early winter show the largest change in the mean precipitation.

Table 9.4.2-1: Model Projected Mean and Climate Normal for NSDF Project for the Mid Term

Period	Temperature (°C)			Precipitation (mm)		
	Climate Normal	Projected Mean	Difference	Climate Normal	Projected Mean	Difference
Annual	5.7	7.8	2.2	852.0	924.1	72.0
Spring	5.0	6.1	1.1	201.1	208.7	7.5
Summer	19.0	21.0	1.9	251.1	263.7	12.7
Fall	7.5	10.8	3.3	243.9	294.7	50.9
Winter	-9.3	-6.8	2.5	155.9	192.6	36.6

°C = degrees Celsius; mm = millimetres

Table 9.4.2-2: Model Projected Mean and Climate Normal for NSDF Project for the Far Term

Period	Temperature (°C)			Precipitation (mm)		
	Climate Normal	Projected Mean	Difference	Climate Normal	Projected Mean	Difference
Annual	5.7	8.6	3.0	852.0	940.6	88.6
Spring	5.0	6.9	1.8	201.1	214.2	13.1
Summer	19.0	21.8	2.8	251.1	265.2	14.1
Fall	7.5	11.6	4.1	243.9	302.6	58.8
Winter	-9.3	-6.0	3.3	155.9	207.0	51.0

°C = degrees Celsius; mm = millimetres

For the Long Term, based on Representative Concentration Pathways (RCPs) described in IPCC's fifth assessment report, global temperatures are predicted to rise between 0.6°C and 7.8°C by the year 3000 (Appendix 9.0-1 Climate Change; Table 9.4.2-3). The majority of the warming will occur before 2300. Changes in precipitation distribution and variability are anticipated to increase after 2100, with an estimated increase in global precipitation of 1°C to 3% per degree Celsius of increase in temperature over the period from 2100 to 3000 (IPCC 2013).

Table 9.4.2-3: Projected Climate for the Mid Term, Far Term, and Long Term

Period	Temperature (°C)	Precipitation (mm)
	Climate Normal	Climate Normal
Current Climate (1994 to 2015)	5.7	852.0
Mid Term Change (2041 to 2070)	2.2	72.0
Far Term Change (2071 to 2100)	3	88.6
Long Term (2100 to 3000)[a]	0.6 to 7.8[b]	1 to 3%/°C[b]

a) Long Term projections are provided as global values, while Current Climate, Mid Term, and Far Term projections represent the NSDF Project site.

b) Projections represent change above those of the reference period of 1986 to 2005.

°C = degrees Celsius; mm = millimetres; %/°C= percentage increase in precipitation per degree Celsius.

9.4.3 Climate Change Effects on the NSDF Project

Climate change may result in shifts in the frequency and/or intensity of the extreme weather events and forest fires. As such, the NSDF Project design features and mitigations described in Section 9.1 Extreme Weather Events and Section 9.2 Forest Fires, respectively, also take into consideration the potential effects of climate change. The effects of climate change are typically measured over longer periods, with the potential for climate change effects increasing as the period over which they are measured increases.

Shifts in the frequency and/or intensity of extreme weather events are expected to accompany the general warming of surface air temperatures. Increased evaporation will result in more moisture in the air and warmer air can hold more moisture, therefore, more intense precipitation events (i.e., rainstorms and snowmelts) are expected. As discussed in Section 9.1 Extreme Weather Events, the WWTP is designed to accommodate a maximum hydraulic flow rate that would be produced during back-to-back 100-year, 24-hour storm events. This was selected as a worst-case design condition for determining the required volume of wastewater equalization. In addition, surface water management design shall consider climate changes over 500 years (post closure design life) and shall incorporate the 2 year, 5 year, 10 year, 25 year, 50 year and 100 year (or prevailing Regional) precipitation storm events and seasonal precipitation averages. For example, historical peak precipitation has been considered in design of surface water management structures (i.e., surface water management ponds, drainage ditches, culverts). The annual snowfall for Canada has increased by about 4% over the time period of 1950 to 2009 (Mekis and Vincent 2011) and the current climate GCMs for the NSDF Project indicate that snowfall is increasing. As well, the conservative freeboard estimate includes the impacts of climate change (a 25% increase in rainfall intensity over the next 100 years) and rain on snowmelt. All building design specifications will meet NBCC 2015 code requirements (NRCC 2015).

As described in Section 9.1 Extreme Weather Events, the ECM base liner and cover have been designed as multi-layer systems to withstand effects from extreme weather events, such as freeze-thaw cycles, extreme rainfall and snowmelt, and high winds. These design features also take into account potential effects from climate change.

Climate change has the potential to greatly influence our country's forests, since even small changes in temperature and precipitation can affect forest growth and survival. A small increase in temperature can result in a longer growing season, increased plant growth, and a shift in tree species occurrence and abundance (NRCAN 2004). None of these biological changes could directly affect the NSDF Project; however, the probability of forest fires increase with dry conditions, as well as lightning strike probability, and a forest fire could affect the NSDF Project infrastructure and workers' safety.

A Closure Plan has been developed as part of the NSDF Project. The intention is for this plan to be an evolutionary document that continues to be refined throughout the life of the NSDF Project. The plan will be reviewed prior to implementation such that changes in environmental conditions (i.e., weather events, forest fires, and seismic events); improved technologies; confirmation of predicted effects; and adaptive management can be integrated. As an adaptation measure for climate change, the potential effects of a changing climate will be considered as part of the re-evaluation of the plan. During the post-closure phase, monitoring will be incorporated into the adaptation management plan to help identify any potential future climate change effects beyond what has been considered in the assessment. This would include evaluating long-term monitoring results, documented changes in the local climate, and up-to-date climate change predictions. Examples of adaptive management to be integrated into closure and post-closure planning could include:

- changes to temperature and precipitation have impacted the vegetation used in the rehabilitation of the site; or
- climate changes (e.g., increased erosion rates) have impacted the final cover system design.

9.5 Glaciation

The earth is currently in an interglaciation period, meaning that it is between ice ages. It is estimated that the current period, called the Holocene, began approximately 11,700 years ago (Clark et al. 2016). Records suggest that previous interglaciation periods have lasted anywhere from 10,000 to 20,000 years (Berger et al. 2003). The global warming projected until the year 3000 (0.6 to 7.8°C over 1000 years) represents a much higher warming rate than the rate seen at the end of the last glacial period (4°C over an estimated 8,000 years). Coupling of climate change models and glaciation models predicts a relatively long interglacial period; the next significant glacial event is not projected to occur before 60,000 years after present (Berger et al. 2003).

Typically, glacial cycles are assumed to be approximately 100,000 years, with the glaciation phase lasting approximately 90,000 years and the deglaciation phase lasting approximately 10,000 years (Peltier 2011). Peltier (2011) also notes that if the concentrations of greenhouse gases remains similar to the present, another glacial event is unlikely due to the increased surface warmth. However, projections for atmospheric concentrations 60,000 years after present are not available, therefore the potential for a glacial event should not be discounted.

Hallet (2011) studied the potential erosion from glacial activity in Kincardine, Ontario. Results of several studies provided a broad range of glacial scouring (erosion resulting from glacial action). The depths ranged from several metres to approximately 300 m at the most over a one million year time scale, assuming a 100,000-year glacial cycle. These studies did not include topographic features or other factors that would tend to localize erosion. In addition, studying the past record of erosion near Kincardine showed a more site-specific estimate of 100 m for a one million-year time scale. No site-specific information was available for the NSDF Project site.

Global warming is projected until the year 3000 (up to about 8°C over 1,000 years; (CNL 2017)). This represents a much higher warming rate than that seen at the end of the last glacial period and corresponds to a higher rate of increase in atmospheric CO_2 concentrations than in previous periods. It is therefore expected that there will be a relatively long interglacial period so that the next glaciation cycle is not likely to be before the year 60,000. It is predicted that glacier will cover the territory of Ontario, which includes the NSDF location, for tens of thousands of years.

Glaciation could positively affect the NSDF Project performance by limiting water infiltration into the ECM and via permafrost impede groundwater movement in the affected strata. At the same time the environment would not be able to sustain human populations, resulting in the absence of potential receptors for radiological exposure. However, a heavy sheet of ice could negatively affect the stability of the ECM and lead to deep erosion of the ECM, resulting in dispersion of waste material once the glacier retreats. It is at this point that potential exposure of returning humans could occur.

Given the inherent uncertainty of a glaciation event, an assessment of the potential effects to humans has been completed in the Performance Assessment Report for the NSDF Project (CNL 2017) using natural analogues. As many naturally occurring ore bodies contain elevated concentrations of radionuclides, these ore bodies provide a point of comparison for analyzing the health and environmental effects of NSDFs. Many of the naturally occurring radionuclides present in these ores have very long radioactive decay times. This means that once relatively short lived radionuclides have decayed, the long-term effects of the near surface disposal of radioactive waste will be similar to the impact of ore bodies that already exist in the natural environment. An evaluation of the existing ore bodies containing radionuclides is provided in Section 8.4 of the Performance Assessment Report (CNL 2017). The assessment concludes that by the time of glacial retreat (approximately 100,000 after present), radionuclide content will have decayed to levels that are less than what is typical for surficial uranium deposits in Canada, and will be below Canadian Soil Quality Guidelines for Uranium (CNL 2017). Consequently, no adverse effects are predicted from a potential glaciation event at the NSDF Project.

9.6 Summary of NSDF Project Design Features and Mitigation

Table 9.6-1 summarizes the design features and mitigation implemented to reduce or eliminate potential effects of the environment on the NSDF Project components and activities.

Table 9.6-1: Environmental Factors That Can Affect the NSDF Project and Associated Mitigation

Project Component or Activity	Factors	Mitigation
Infrastructure and Support Facilities	Extreme Events	Extreme events (e.g. storms) may result in a potential interaction with infrastructure and support facilities, but this is accounted for in the design specifications and will be addressed through ongoing maintenance. For example, all building layouts will meet NBCC 2015 code requirements. The effects of the probable maximum precipitation was considered by identifying flow paths and possible risk to infrastructure.
Wastewater Treatment Plant	Rain, Extreme Events	Extreme rainfall and snowmelt events and the potential for flooding is considered in the design of the WWTP. The maximum hydraulic flow rate was determined by evaluating the expected contact stormwater volume that would be produced during back-to-back 100-year, 24-hour storm events. This was selected as a worst-case design condition for determining the required volume of wastewater equalization.
Drainage Ditches and Culverts	Rain, Extreme Events	Extreme rainfall and snowmelt events and the potential for flooding is considered in the design of the surface water management systems. All roadways, including the perimeter road, have ditches that convey not only roadway drainage, but drainage from adjacent lands, to the surface water management ponds. These have been designed to convey the 25-year post-development peak design flow, which includes consideration of climate change. For example, historical peak precipitation has been considered in design of drainage ditches and culverts. Where drainage crosses roadways, culverts are sized to convey the 25-year design event without road overtopping. Annual maintenance activities will identify any erosion or blockage problems for ditches and culverts. In addition, a maintenance review will be completed after major storm events and after the annual spring melt to confirm there are no major erosion or blockage issues at the culvert and sewer inlet or outlet.
Surface Water Management Ponds	Rain, Extreme Events	Extreme rainfall and snowmelt events and the potential for flooding is considered in the design of the surface water management ponds. The current surface water management pond design considers climate change over 500 years and reflects the overall storage required to control flows for the 2-year through to 100-year rainfall events at the site. This volume also contains the storage required for sediment control during construction and water quality control during operations. The current footprints typically assume a maximum 100-year operating water level at a 3 m depth with 1 m of freeboard that includes allowance for climate change impacts and rain on snowmelt. Major system (i.e., 100-year) flow routes follow the road system and ditches to the relevant surface water management ponds. The probable maximum precipitation (PMP) flow generally follows the major system route using the roadway, related ditches and adjacent lands. The PMP flow will exceed the surface water management ponds attenuation capacity, but is adequately conveyed by inlet and emergency outlet structures adjacent to the surface water management ponds.
Engineered Containment Mound Berm	Rain, Extreme Events	Severe rainstorms or snowmelts could also affect roads and cause failure of natural or engineered slopes (e.g., berms). Designed berms consist of three main geotechnical elements, or layers, each contributing to the soundness and integrity of the berm itself and the whole ECM.

Table 9.6-1: Environmental Factors That Can Affect the NSDF Project and Associated Mitigation

Project Component or Activity	Factors	Mitigation
Engineered Containment Mound and Berm	Seismic	Should a seismic event occur at or near the NSDF Project site, this could lead to a rupture of soil material beneath the ECM and potentially result in a failure of the engineered berms and cover, resulting in damage to ECM liners and the leachate collection system. The NSDF Project facilities, including the final cover design, are designed to meet safety factors and earthquake loading requirements. To support the design of the NSDF Project, a Probabilistic Seismic Hazard Assessment (PSHA) was prepared and an analysis of liquefaction potential was conducted; mitigation measures will be implemented into the design of the ECM. Based on the conclusions of the seismic analysis, the ECM is expected to remain functional under the 10,000-year design seismic event scenario. During operations through the post-closure institutional control phases of the NSDF Project, the consequences of any damage to the engineered berms or the ECM cover from a beyond design earthquake would be mitigated as required.
Engineered Containment Mound Cover	Extreme Rain and Wind	Natural events could cause erosion of the ECM cover, leading to water infiltration into the waste. The final cover is designed to limit water infiltration, to direct infiltration and surface water runoff away from the ECM waste emplacement area, and to resist degradation by surface geologic processes and biotic activity (e.g., prevent burrowing of animals) and inadvertent intruder attempts to access or excavate into the waste cells. A series of drainage control features will be installed in conjunction with placement of final cover over the ECM. The finished surface of the ECM is elevated from the surrounding terrain, which limits the quantity of surface water entering the ECM from areas outside the extent of the ECM. The topographical slopes within the ECM footprint are sufficient to promote drainage, and by lining the ECM surface water collection ditches and stilling basins with rip rap and other erosion control measures, sediment transport and erosion will be minimized. Meteorological records will be reviewed annually to confirm that the cover performance is not overloaded in any post-closure year.
Engineered Containment Mound Cover and Liner	Temperature	Natural freeze-thaw cycles could damage the ECM cover, leading to water infiltration into the waste. The NSDF Project has been designed to include a layer of clean fill on the floor of the ECM of sufficient thickness to prevent freezing of the basal liner systems prior to waste placement. The HDPE geomembrane liner components of the sideslope lining system will not be adversely affected by freeze thaw cycles, whereas the geosynthetic and compacted clay liner components of the sideslope lining system could undergo an increase in hydraulic conductivity prior to placement of the wastes on the sideslopes. However, after placement of the waste, the clay liners will consolidate under the weight of the waste healing the voids caused by freezing. The final cover system will be installed to its full thickness progressively as areas of the ECM reach the final waste contours. The final cover system design has 1.75 m of granular/soil materials above the lining system, which is sufficient to prevent freezing of the final cover liner components.

Table 9.6-1: Environmental Factors That Can Affect the NSDF Project and Associated Mitigation

Project Component or Activity	Factors	Mitigation
Reclamation	Temperature, Precipitation	Grading of the site will be designed taking into consideration the potential for future extreme weather events. Changes to temperature and precipitation may affect the vegetation used in reclamation of the site and will be considered in the closure and post-closure planning. For example, the vegetated top of the final cover system will be designed for withstanding erosion and gully initiations. The vegetation for the final cover will be limited to grass species that are maintenance-free and drought-resistant. Vegetation will be established and maintained by watering, fertilizing, weeding, mowing, trimming, dethatching, core aerating, replanting, and performing other operations as required to establish healthy, viable grassy vegetation. Treatments will be applied as required to keep grass and soil free of pests and pathogens or disease. Changes to climate can be addressed through adaptive management plans that consider projected changes in climate relevant to the local vegetation.

Note: The factors include consideration of the shifts in frequency and/or intensity of these events due to climate change.

10.0 SUMMARY OF MONITORING AND FOLLOW-UP PROGRAMS

In the discipline assessments undertaken in Section 5.0 of the Environmental Impact Statement (EIS), Canadian Nuclear Laboratories (CNL) has proposed monitoring and follow-up to be undertaken during the construction, operations, and closure/post-closure stages of the Near Surface Disposal Facility (NSDF) Project. These programs will serve to address the uncertainties associated with the effects predictions and the performance of mitigation, verify the effects predictions, and identify any unanticipated effects and provide for the implementation of adaptive management to limit these effects.

A summary of the proposed environmental assessment monitoring and follow-up programs discussed in each discipline-specific study in Sections 5.2 through 5.10 of the EIS is presented in Table 10.0-1. The programs will be carefully integrated with ongoing monitoring and management plans, and where appropriate, and will include or reference CNL Standard Practices and Procedures. Wherever possible, existing programs will be adapted to meet the objectives of monitoring the predictions made by the environmental assessment for the NSDF Project.

The follow-up monitoring plan presented in the section is conceptual in nature and provides a preliminary description of the activities and framework for monitoring proposed for the NSDF Project. The follow-up monitoring program will be further detailed as detailed project design is finalized, which may influence the nature, frequency and locations of monitoring. In addition, input from regulatory agencies, First Nation and Métis communities, and the public will be considered. The detailed follow-up monitoring plan will include sufficient information on the type, quantity and quality of information required to reliably verify predicted effects (or absence of them) and confirm the effectiveness of mitigation measures. These plans will also be prepared consistent with relevant CSA N288 Standards, where applicable.

Existing compliance programs are listed below; a summary of each of these programs is provided in Section 3.13.2 of the EIS.

- Radiation Protection Program;
- Environmental Protection Program;
- Waste Management Program;
- Occupational Safety and Health Program;
- Emergency Preparedness Program;
- Nuclear Criticality Safety Program;
- Physical Security Program;
- Nuclear Materials and Safeguards Management Compliance Program; and
- Fire Protection Program.

Monitoring and follow-up will be completed by CNL. The Vice President of Health, Safety, Security and Environment & Quality will be responsible for the delegation of resources to develop, implement and integrate the environmental assessment monitoring and follow-up programs identified in Table 10.0-1. The development and implementation of mitigations identified for the NSDF Project and housed in the monitoring and follow-up programs are tracked in relevant management plans, with roles and responsibilities clearly defined in each plan. Monitoring and follow-up programs will be carried out throughout all phases of the NSDF Project. The following phases were identified for the NSDF Project.

- **Construction Phase**: includes site preparation and all activities associated with the construction of the NSDF, up until the operations phase commences with the delivery of waste. This phase includes installing the necessary supporting and/or ancillary facilities and NSDF infrastructure to facilitate NSDF operations, inactive commissioning and systems testing, and receipt of radioactive and mixed waste. Construction activities are expected to be completed by 2020.
- **Closure Phase:** includes activities necessary to complete the installation of the final cover and implementation of long-term monitoring. Closure activities are expected to start in 2070 and continue through to 2100, after which the NSDF Project will transfer into the post-closure phase.
- **Post-closure Phase:** has two discrete periods: Institutional Control and post-Institutional Control. The Institutional Control period includes implementation of both active and passive control throughout 2100 to 2400 (i.e., 300 years). During Institutional Control, groundwater monitoring and groundwater quality management will continue to demonstrate compliance with the safety case assumptions. Post-institutional Control occurs after year 2400 and continues indefinitely.

10.1 Data Management

The development and implementation of mitigations identified for the NSDF Project and housed in the monitoring and follow up programs are tracked in relevant management plans, where data management, including collection, storage, standards and responsible roles, are defined. Data collected will meet the required guidelines for collection and quality assurance and control. Canadian Nuclear Laboratories will store information generated from the environmental assessment monitoring and follow-up program in a robust database for future analysis and reporting. Analysis of results from the monitoring and follow-up program will be reported and submitted to the relevant regulatory agencies as required.

10.2 Adaptive Management

Canadian Nuclear Laboratories is committed to achieving continual improvement in environmental performance through its management systems. CNL manages environmental related matters through an existing Environmental Management System. The Environmental Management System is registered within the requirements of the International Organization for Standardization 14001:2004 standard (International Organization for Standardization 2004). The Environmental Management System includes compliance and improvement systems to evaluate areas for improvement or trending. It will continue to be implemented for the Project construction and operations and will be updated, as needed, as part of an annual management review process.

The development and implementation of all mitigations identified for the NSDF Project and housed in the monitoring and follow up programs are tracked in relevant management plans. CNL's approach to adaptive management is defined in each plan. As site conditions and monitoring dictate, or as new technology emerges, CNL will adaptively manage site practices and monitoring programs to meet the defined objectives. For some programs, this involves regular evaluation of predictive models; which are clearly defined in each applicable management plan.

If the environmental monitoring and follow-up program identifies that adverse environmental effects are greater than predicted, then CNL will evaluate whether they result in changes to the conclusions in this EIS. If changes are confirmed, then CNL will evaluate the need for revised mitigation actions and management practices to manage effects. Where the need for revised mitigations is identified they will be developed and implemented.

10.3 Engagement and Communication

Recognizing people's interest in understanding and participating in decisions that affect them, CNL will proactively seek, engage, and support meaningful discussion on issues and opportunities related to the NSDF Project, including the monitoring and follow-up program, with Aboriginal peoples and communities of interest as part of the Public Information Plan and Aboriginal Engagement Plan. Canadian Nuclear Laboratories will continually evaluate both the process and the outcome of the ongoing engagement and communication activities to address and manage issues as they arise.

This page intentionally left blank

Table 10.0-1: Environmental Assessment Monitoring and Follow-up Programs Proposed for the NSDF Project

EIS Section	Valued Component	Project Phase and Potential Effect	Monitoring Program Objective	Conceptual Monitoring Program	Suggested Duration	Implementing Program
Section 5.2 Atmospheric Environment	Air Quality	Construction activities will result in fugitive dust emissions.	■ Verify that mitigation measures are being implemented effectively. ■ Verify predictions are within air quality criteria.	■ Application of aggregate to unpaved roads – a record will be kept of the date of each application of aggregate to unpaved roads. ■ Road misting – a record will be maintained of road misting. ■ Site inspection – during periods of high dust susceptibility, regular inspections will be carried out to monitor the efficacy of dust mitigation and any potential concerns with regards to fugitive dust, and if required implementation of mitigation measures will be recommended. Environmental conditions will be recorded. ■ Particulate monitoring – Total suspended particulates (TSP) using a high volume sampler.	Through the construction phase	Dust Management Plan to be developed and implemented for the NSDF Project.
		Operations activities will result in fugitive dust emissions.	■ Verify that the following mitigation measures are being incorporated as planned, and are effective. ■ Verify predictions are within air quality criteria.	■ Application of aggregate to unpaved roads – a record will be kept of the date of each application of aggregate to unpaved roads. ■ Road misting – a record will be maintained of road misting. ■ Site inspection – during periods of high dust susceptibility, regular inspections will be carried out to monitor the efficacy of dust mitigation and any potential concerns with regards to fugitive dust, and if required implementation of mitigation measures will be recommended. Environmental conditions will be recorded. ■ Vehicle decontamination – a record will be kept of the number of waste delivery vehicles recorded thru the vehicle decontamination facility. ■ Particulate monitoring – TSP high volume sampler.	Based on observations and monitoring data during first year of operation, the frequency of monitoring would be reevaluated.	Captured through the implementation of CNL's Procedure for Management and Monitoring of Emissions, which includes operational control monitoring and verification monitoring.
	Greenhouse gases	Greenhouse Gas (GHG) emissions from the decomposition of waste during operations and closure.	■ Verify that the measures for controlling landfill gas generated from wasted deposited in the Engineered Containment Mound (ECM) during operations and following final closure are adequate ■ Verify that methane emission rates used in the assessment are reasonable and conservative.	■ Monitoring for methane will be performed using handheld portable combustible gas meter detectors. ■ A passive landfill gas venting system will be constructed contemporaneously with installation of the ECM final cover system. ■ The LFG monitoring probes will also be installed around the perimeter of the ECM to detect evidence of potential LFG migration away from the ECM.	Periodic monitoring during operations and for a specific period of time during closure phase (during which the frequency may be progressively reduced and possibly ultimately eliminated if no evidence of LFG migration from the ECM is detected)	Landfill Gas Monitoring Program to be developed and implemented for the NSDF Project.
		Construction and Operations activities will result in increased greenhouse gas emissions.	Verify that GHG emission rates used in the assessment are reasonable, but conservative. Monitoring results will be used for GHG reporting requirements.	Fuel Usage – a record will be kept of the fuel usage related to the NSDF Project.	Annual estimations and GHG reporting, as required	Captured through the implementation of CNL's Procedure for Management and Monitoring of Emissions, which includes operational control monitoring and verification monitoring.

Table 10.0-1: Environmental Assessment Monitoring and Follow-up Programs Proposed for the NSDF Project

EIS Section	Valued Component	Project Phase and Potential Effect	Monitoring Program Objective	Conceptual Monitoring Program	Suggested Duration	Implementing Program
Section 5.3 Geological and Hydrogeological Environment	Hydrogeology	The NSDF may affect groundwater quality during operation, closure and post-closure	■ Verify Environmental Assessment (EA) predictions on groundwater from the ECM and Waste Water Treatment Plant (WWTP) operation. ■ Verify the effectiveness of mitigation.	■ Water elevation measurements to determine groundwater flow direction and gradients ■ Sampling to confirm groundwater quality to detect potential releases of constituents from the ECM containment area ■ Initial sampling frequency will likely be twice per year (Spring and Fall).	Groundwater monitoring will continue through operations, closure and post-closure. The number of parameters and locations may change based annual review of monitoring data.	NSDF Project groundwater monitoring will be integrated into the overall CNL Groundwater Monitoring Program, and will be compliant with CSA N288.7-15.
Section 5.4 Surface Water Environment	Hydrology	The installation of the ECM will physically alter drainage patterns, and may change downstream discharge, water levels in adjacent wetlands, and channel/bank stability.	Operational monitoring – Verify the surface water management pond is performing as designed.	Support the development of hydrographs of surface water management pond inflow and outflow. Outflow would be based on theoretical stage-discharge rating curves for weir and orifice outlets and inflow based on routing that uses stage-storage and stage-discharge curves for the particular surface water management pond in question.	The water level at the surface water management pond will be monitored during construction and operation. The need for and duration of monitoring will be reviewed based annual review of monitoring data.	Integrated into the NSDF Project Environmental Protection Plan to be developed and implemented for the NSDF Project.
			Environmental monitoring – Confirm that the ecological function and structure of the wetland system is maintained.	Monitoring of wetland water elevations to determine changes from the presence of the ECM.	Water level monitoring of the wetland system will be initiated pre-construction (baseline) and continue through construction and operations. The need for and duration of monitoring will be reviewed based annual review of monitoring data.	Water-level monitoring of the wetland system will be integrated into the CNL Environmental Monitoring Program.
	Surface Water Quality	■ Discharge of treated effluent from the WWTP to the East Swamp Wetland can cause changes to downstream surface water quality. ■ Leakage of leachate from the ECM during the post-closure phase (i.e., after Year 2400) from liner and cover failure as a result of normal evolution can cause changes to downstream surface water quality.	Environmental monitoring – Verify EA predictions related to surface water quality.	Monitor the quality of surface water surrounding the ECM footprint area to evaluate whether the quality of the water is impacted by the ECM or by operation of surface water management pond(s)	Water quality monitoring will continue through operations, closure and post-closure. The number of parameters and locations may change based annual review of monitoring data.	Surface water monitoring in the receiving environment is integrated into the CNL Environmental Monitoring Program.
			■ Operational monitoring – Verify the surface water management pond is performing as designed. ■ Demonstrate compliance with site-specific effluent limits developed for the NSDF Project.	■ Visual inspections and surface water sampling will be carried out to identify leachate seeps, characterize the surface water chemistry in perimeter ditches in relation to applicable surface water protection objectives, and determine if contingency measures are warranted. ■ Each pond weir outlet water quality will be sampled identify if any contact surface water or leachate contamination is entering the surface water management ponds. ■ WWTP effluent verification monitoring consistent with CSA Standard N288.5-11.	■ Routine visual inspections and surface water sampling during operation, closure, and post-closure, as required. ■ Effluent monitoring will continue throughout operation of the WWTP.	Effluent water quality monitoring will be integrated into the CNL Effluent Verification Monitoring Program.

Table 10.0-1: Environmental Assessment Monitoring and Follow-up Programs Proposed for the NSDF Project

EIS Section	Valued Component	Project Phase and Potential Effect	Monitoring Program Objective	Conceptual Monitoring Program	Suggested Duration	Implementing Program
Section 5.5 Aquatic Environment	■ Fish ■ Fish Habitat	■ No residual adverse effects identified. Potential effects are related to: ▪ Change to local hydrology from surface disturbances may cause changes to water levels, flows and channel/bank stability at downstream locations, affecting water and sediment quality, and fish and fish habitat ▪ Surface water drainage through the Project site during construction of the ECM may transport blasting residuals and metals directly into downstream waterbodies, affecting surface water and sediment quality, and fish and fish habitat ▪ Air and dust emissions (including sulphur dioxide, nitrogen oxides, and particulate matter) and subsequent deposition may cause a change in surface water and sediment quality, affecting fish and fish habitat. ▪ Discharge of domestic wastewater may cause a change in surface water and sediment quality, affecting fish and fish habitat.	Verify effects predictions for surface water quality (and subsequent effects to fish).	Monitoring and follow-up programs are not specifically identified for aquatic biodiversity; rather, operational monitoring (i.e., sampling of treated effluent in the storage tanks prior to discharge) and monitoring programs developed for groundwater and surface water quality will be implemented, as described above.	Water quality monitoring will continue through operations, closure and post-closure. The number of parameters and locations may change based annual review of monitoring data.	Routine surface water quality monitoring and flow in East Swamp and Perch Creek monitoring is ongoing as part of CNL's Environmental Monitoring Program.

Table 10.0-1: Environmental Assessment Monitoring and Follow-up Programs Proposed for the NSDF Project

EIS Section	Valued Component	Project Phase and Potential Effect	Monitoring Program Objective	Conceptual Monitoring Program	Suggested Duration	Implementing Program
Section 5.6 Terrestrial Environment	Canada warbler	■ **Habitat Availability**: Permanent, direct loss of 25 ha of suitable habitat. Long-term reduction in quality of nesting habitat and possible avoidance in the LSA from sensory disturbance. ■ **Habitat Distribution**: Small, permanent change in local movement **Survival and Reproduction**: Small reduction in reproductivity from sensory disturbance	Verify EA predictions through collection of data on relative abundance and other key demographic parameters for breeding bird populations that overlap with the RSA	Data on relative abundance and other key demographic parameters for breeding birds in the RSA will be used to evaluate trends in populations of breeding birds that overlap with the Regional Study Area (RSA), including Canada warbler, eastern whip-poor-will and golden-winged warbler. If declining trends are observed for these species in the RSA, then the need for additional mitigation measures will be evaluated in consultation with Environment and Climate Change Canada (ECCC).	Every 5 years	Monitoring Avian Productivity and Survivorship (MAPS) Program is integrated into CNL's existing Species at Risk program
	Eastern whip-poor-will	■ **Habitat Availability:** Permanent, direct loss of 1 ha of suitable habitat ■ **Habitat Distribution**: Small, permanent change in local movement **Survival and Reproduction**: Small reduction in reproductivity from sensory disturbance	Verify EA predictions through collection of data on relative abundance and other key demographic parameters for breeding bird populations that overlap with the RSA	Data on relative abundance and other key demographic parameters for breeding birds in the RSA will be used to evaluate trends in populations of breeding birds that overlap with the RSA, including Canada warbler, eastern whip-poor-will and golden-winged warbler. If declining trends are observed for these species in the RSA, then the need for additional mitigation measures will be evaluated in consultation with ECCC.	Every 5 years	Monitoring Avian Productivity and Survivorship (MAPS) Program is integrated into CNL's existing Species at Risk program
	Golden-winged warbler	■ **Habitat Availability:** Permanent, direct loss of 24 ha of suitable habitat ■ **Habitat Distribution**: Small, permanent change in local movement **Survival and Reproduction**: Small reduction in reproductivity from sensory disturbance	Verify EA predictions through collection of data on relative abundance and other key demographic parameters for breeding bird populations that overlap with the RSA	Data on relative abundance and other key demographic parameters for breeding birds in the RSA will be used to evaluate trends in populations of breeding birds that overlap with the RSA, including Canada warbler, eastern whip-poor-will and golden-winged warbler. If declining trends are observed for these species in the RSA, then the need for additional mitigation measures will be evaluated in consultation with ECCC.	Every 5 years	Monitoring Avian Productivity and Survivorship (MAPS) Program is integrated into CNL's existing Species at Risk program

Table 10.0-1: Environmental Assessment Monitoring and Follow-up Programs Proposed for the NSDF Project

EIS Section	Valued Component	Project Phase and Potential Effect	Monitoring Program Objective	Conceptual Monitoring Program	Suggested Duration	Implementing Program
Section 5.6 Terrestrial Environment (cont'd)	Bats	■ **Habitat Availability:** Permanent, direct loss of 25 ha of potential maternity roosting habitat ■ **Habitat Distribution:** Gap in potential maternity roosting habitat, but negligible change in local movement patterns ■ **Survival and Reproduction:** No residual effects due to the NSDF Project	■ Offset the incremental contribution of the NSDF Project to the loss of potential maternity roosting habitat in the SSA ■ Verify effectiveness of mitigation by determining number of individuals and species of bats using boxes for roosting habitat	■ Inherent uncertainty on the current status of bat populations overlapping the RSA and uncertainty regarding the amount and relative importance of maternity roost habitat that will be lost as a result of the NSDF Project is the main rationale for installing bat boxes as mitigation / off-setting. Further, CNL is planning to remove over 100 buildings in the built-up area that potentially host bat species either during the breeding season or during hibernation, and installing additional bat boxes at the NSDF Project is intended to also offset the future removal of these anthropogenic structures. ■ Offsetting the removal of unoccupied bat maternity roost trees is not required under SARA; however, bat boxes are relatively inexpensive and can be highly effective at providing habitat for roosting little brown myotis and possibly northern myotis. Tri-colored bats are less likely to use bat boxes, but may use other forms of artificial roosting habitat; these options may be considered. Installation of bat boxes in suitable locations in the RSA is recommended to offset the incremental contribution of the NSDF Project to cumulative effects on SARA-listed bats. ■ In consultation with CNL biologists, and in consideration of future losses of anthropogenic structures that may provide roosting habitat, offsetting in the form of 16 bat boxes is recommended. Each 4-chambered box (Bat Conservation International approved design) will be installed back-to-back on galvanized steel poles (galvanized steel to reduce predator access). These will require installation at a total of 8 locations (2 boxes per pole, per location). This box design is suggested to have capacity for 350-400 individual bats per house, providing roosting habitat for a potential maximum of 6,400 individual bats (with 16 boxes). ■ Criteria for appropriate siting will include: accessibility of box locations for installation and future monitoring of utilization / effectiveness, avoidance of areas with radiological contamination in surface water features, and appropriate distance to anthropogenic disturbances to avoid sensory effects (i.e., noise). Immature forested areas adjacent to larger uncontaminated waterbodies and wetlands are high priority locations, because these forest types do not currently provide high quality roosting habitat and would be most benefited by installation of bat roost boxes to expand the spatial coverage of potential roosting habitat within the RSA. Final site selection will be at the discretion of CNL biologists. ■ Monitoring will be conducted to determine if boxes are being used. Boxes not being used may be moved to an alternate location.	Bat boxes should remain in place throughout Operations. Monitoring should take place annually for three years	■ Monitoring will be integrated into CNL's existing Species at Risk program
	Blanding's turtle	■ **Habitat Availability:** Direct, permanent loss of 22 ha of critical habitat ■ **Habitat Distribution:** Permanent change in local movement ■ **Survival and Reproduction:** Mortality of individuals over the lifespan of the NSDF Project	Confirm effectiveness of mitigation through tracking wildlife mortality and use information for adaptive management	Wildlife-vehicle collision monitoring – Vehicle-caused Blanding's turtle mortality will be reported and data will be compiled in a database that can be used to inform adaptive management for the site.	On-going during Construction and Operations and Closure	Monitoring will be integrated into CNL's existing Species at Risk program
			Confirm effectiveness of road mitigation to minimize or eliminate the potential for road mortality in the LSA	Road mitigation plan – Comprehensive assessment of high risk crossing locations for Blanding's turtles. Consideration of the location and type of existing crossing culverts as passageways or upgrade or install new crossing structures that are conducive to Blanding's turtle safe passage under the roads. Install permanent fencing on either side of the roadway at these crossing locations to funnel turtles into the passage culvert and prevent them from going on the road. Monitor the fencing to identify gaps or improperly functioning sections to be repaired. Monitoring the culvert passages to determine if Blanding's turtles are using the culvert passages to cross under the road. Install remote cameras within the culverts to determine their usage.	On-going during Construction and Operations and Closure	Monitoring will be integrated into CNL's existing Species at Risk program

Table 10.0-1: Environmental Assessment Monitoring and Follow-up Programs Proposed for the NSDF Project

EIS Section	Valued Component	Project Phase and Potential Effect	Monitoring Program Objective	Conceptual Monitoring Program	Suggested Duration	Implementing Program
Section 5.7 Ambient Radioactivity and Ecological Health Section 5.8 Human Health	All VCs	■ No residual adverse effects identified. Potential effects are related to: ▪ Release of emissions from the ECM from radioactive dust created during handling of bulk materials and emissions of gases during operations. ▪ Release of emissions from the WWTP to air during operations and closure. ▪ Discharge of treated effluent from the WWTP to the East Swamp Wetland during operations and closure can cause changes to groundwater quality in the wetland and downstream surface water quality. ▪ Release of radioactive of gases from materials in the ECM during operations, closure and post-closure phases. ▪ Leakage of leachate from the ECM during the post-closure phase (i.e., after Year 2400) from liner and cover failure as a result of normal evolution can cause changes to groundwater quality in the wetland and downstream surface water quality	Verify mitigation measures are effective	■ Monitoring for air quality as noted above (i.e., for dust) and air effluent verification monitoring at the WWTP. Samples collected in the high volume air sampler will be screened for radioactivity. ■ Monitoring of treated effluent, stormwater pond effluent and surrounding surface water quality, as noted above ■ Ambient radioactivity will be measured at the NSDF site. ■ Groundwater monitoring surrounding the ECM, as noted above.	■ On-going during Operations, Closure and Post-closure. The need for and duration of monitoring will be reviewed based annual review of monitoring data. ■ Dust monitoring would be initiated during the construction phase.	Integrated into the CNL Effluent Verification and Environmental Monitoring Programs.
Section 5.9 Land and Resource Use	■ Land and Resource Tenures and Other Registered Interests ■ Outdoor Tourism and Recreation ■ Archaeological Sites ■ Traditional Land and Resource Use by First Nation and Métis Communities	■ No residual adverse effects identified. Potential effects are related to: ▪ Changes in access to or quality and quantity of outdoor tourism and recreation activities. ▪ Ground disturbance from the NSDF Project during construction may cause disturbance or destruction to archaeological sites. ▪ Changes in access to or quality and quality of traditional land use activities.	Verify mitigation measures are effective	■ Monitoring and follow-up programs are not specifically identified for land and resource use; rather, monitoring for environmental pathways noted above (i.e., for air quality, water quality and groundwater quality) will be implemented to verify effects predictions for land and resource use. ■ CNL will continue to engage with local communities, municipalities, and First Nation and Métis groups. ■ Follow-up programs for archaeological resources are anticipated to be minimal as most mitigation measures for archaeological resources are applied and completed in advance of ground disturbance activities. Monitoring will be used to identify unanticipated archaeological resources and implement adaptive management.	On-going during Operations, Closure and Post-closure. The need for and duration of monitoring will be reviewed based annual review of monitoring data.	■ Integrated into the CNL Environmental Monitoring Program. ■ Executed as part of CNL's Public Information Program. ■ Implementation of the Cultural Resource Management portion of the Environmental Protection Program.

Table 10.0-1: Environmental Assessment Monitoring and Follow-up Programs Proposed for the NSDF Project

EIS Section	Valued Component	Project Phase and Potential Effect	Monitoring Program Objective	Conceptual Monitoring Program	Suggested Duration	Implementing Program
Section 5.10 Socio-economic Environment	■ Labour Market ■ Economic Development ■ Government Finances ■ Housing and Accommodations ■ Services and Infrastructure ■ Quality of Life ■ Public Safety	■ No residual adverse effects identified. Potential beneficial effects identified. Potential effects are related to: ▪ direct and indirect employment requirements may affect employment and income with the local and regional study areas; ▪ the NSDF Project may provide contracting and supplier opportunities to local and regional businesses; ▪ the NSDF Project could increase pressure on commercial accommodations; ▪ changes in demand for community services (health, education, protective and emergency services) with respect to the capacity of LSA services to meet the demand; and ▪ the NSDF Project could increase road degradation due to increased traffic volume from the transportation of workers, supplies, and equipment during the construction phase.	Verify mitigation measures are effective.	■ Monitoring and follow-up programs are not specifically identified for socio-economics; rather, monitoring for environmental pathways noted above (i.e., for air quality, water quality and groundwater quality) will be implemented to verify effects predictions. ■ CNL will proactively seek, engage, and support meaningful discussion on issues and opportunities related to the NSDF Project. ■ CNL will continually evaluate both the process and the outcome of the ongoing engagement and communication activities to address and manage issues as they arise.	■ On-going during construction, operations and closure. The need for and duration of monitoring will be reviewed based annual review of monitoring data. ■ The level and nature of engagement with the communities will depend on feedback received.	■ Integrated into the CNL Environmental Monitoring Program. ■ Executed as part of CNL's Public Information Program.

ha = hectare.

This page intentionally left blank

11.0 CONCLUSIONS

This Environmental Impact Statement (EIS) describes the NSDF Project, the existing environmental conditions on the CRL site, and assesses the likely effects of the Project on the environment. The EIS also includes an assessment of likely cumulative effects of the Project in combination with other past, present or reasonably foreseeable projects, as required. It describes the effects for normal conditions and as a result of accidents and malfunctions. The EIS also describes and assesses the likely effects of the environment on the Project.

The development of a near surface disposal facility for radioactive waste at CRL would reduce potential risks associated with the CNL legacy wastes, liabilities, and create the conditions for the revitalization of the CRL property. The NSDF Project would enable the remediation of contaminated lands and legacy waste management areas, and decommissioning of outdated infrastructure at the CRL property and CNL's other business locations. The current CRL waste management practice is to safely store radioactive waste on-site in individual facilities in accordance with current licence conditions. The proposed NSDF would accommodate the disposal of current and future radioactive waste at the site in a manner that is protective of human health and the environment.

The significance of the likely environmental effects of the NSDF Project has been assessed in Section 5.0 Environmental Effects. A summary of the residual adverse effects, mitigation measures and significance of residual adverse effects is provided in Table 8.0-1 of Section 8.0. The proposed monitoring and follow-up programs to be undertaken during construction, operations and throughout the closure and post-closure phases are summarized in Section 10.0 Summary of Monitoring and Follow-up Programs.

Residual adverse effects were identified for air quality, hydrogeology, hydrology, surface water quality, terrestrial biodiversity, socio-economics (housing and accommodations, and services and infrastructure). Beneficial effects were identified for socio-economics (labour market, economic development). Based on the evaluation, each of the residual adverse effects was assessed to be not significant, with the exception of bats and Blanding's turtle.

For both bats and Blanding's turtle, the Base Case is assessed to be significant because of existing cumulative effects on the species. For bats, white nose syndrome has resulted in dramatic declines of these species across the eastern portions of their Canadian range. All three bat species evaluated (i.e., little brown myotis, northern myotis and tri-colored bats) are inherently resilient to changes in their habitat based on their high degree of mobility, and one of the three species, little brown myotis, is well adapted to human disturbance, commonly using human structures, such as bat boxes, for maternity roosting habitat. Bat boxes will be installed at suitable locations to mitigate the adverse effects resulting from the NSDF Project. As such, the NSDF Project will contribute a small increment to the existing significant adverse cumulative effect on these species.

Two of the primary threats to Blanding's turtle are land conversion and road networks. The NSDF Project footprint would permanently remove proposed critical habitat during construction. The NSDF Project will also result in a change in movement patterns. In addition, the increase in traffic related to the NSDF Project will consequently increase the risk of road injury or mortality to Blanding's turtle. Risks to Blanding's turtle will be mitigated through installation of fencing around the NSDF Project site and implementation of a comprehensive road mitigation plan. Concerted efforts to reduce the risk of mortality among juveniles and adults of the population that overlaps the RSA is required and will be implemented to enhance the chance of survival for this population.

Overall, it is CNL's conclusion that with the identified mitigation measures, the implementation of the NSDF Project is not likely to result in significant residual adverse effects on most environmental components. For bats and Blanding's turtle, significant adverse effects are related to the existing conditions for these species and not due to the NSDF Project; the NSDF Project will contribute a small increment to existing signifant adverse cumulative effect on these species.

No residual effects were identified for human health during the NSDF Project life cycle. The maximum estimated dose to the potential critical groups, that is the most exposed members of the public, during the operations period represent less than 0.01% of both the regulatory limit of 1 millisieverts per year (mSv/y) and the CRL licensing limit of 0.3 mSv/y. During post-closure phases, the maximum estimated dose is 0.02% of the regulatory dose limit of 1 mSv/y and 0.07% of the licensing limit of 0.3 mSv/y. Residual effects on Ottawa River water quality are determined to be negligible during operations and post-closure phases and may even result in the net reduction due to remediation of legacy waste storage areas.

During operations, leachate from the engineered containment mound will be collected and treated to remove radiological and non-radiological contaminants. Tritium concentrations in Perch Creek discharging to the Ottawa River will not exceed the drinking water guideline. Surface water quality monitoring will be conducted as part of CNL's Environmental Monitoring Program to verify water quality predictions.

12.0 REFERENCES

Section 1.0 – Introduction

AECL (Atomic Energy of Canada Limited). 2013. Safety Analysis Basis: CRL Site Characteristics. CRL-03510-SAB-001. Revision 3. January 2013.

Canadian Environmental Assessment Act, 2012. SC 2012, c 19, s 52. Available at: http://canlii.ca/t/51zdg

CNL (Canadian Nuclear Laboratories). 2016. Environmental Assessment (and/or Environmental Effects Review). Project Description: Near Surface Disposal Facility at Chalk River Laboratories. 232-509200-ENA-001. Revision 0. March 2016.

CNL. 2015a. Environmental Monitoring in 2014 at Chalk River Laboratories. Annual Safety Report. CRL-509243-ASR-2014. Revision 0. June 2015.

CNL. 2015b. Environmental Policy, CW-514100-POL-003, Revision 1.

CNSC (Canadian Nuclear Safety Commission). 2016a. Generic Guidelines for the Preparation of an Environmental Impact Statement pursuant to the *Canadian Environmental Assessment Act, 2012*. May 2016. ISBN: 978-0-660-05139-0.

CNSC. 2016b. REGDOC-3.2.2. Public and Aboriginal Engagement: Aboriginal Engagement. February 2016. ISBN: 978-0-660-04518-4.

CNSC. 2016c. REGDOC-2.9.1. Environmental Protection: Environmental Principles, Assessments and Protection Measures. December 2016. ISBN: 978-0-660-06255-6

CNSC. 2006. Regulatory Guide G-320. Assessing the Long Term Safety of Radioactive Waste Management. December 2006. ISBN: 978-0-662-44692-7.

CSA Group. 2012a. CSA N286-12: Management System Requirements for Nuclear Facilities. Available at: http://shop.csa.ca/en/canada/nuclear/n286-12/invt/27022422012

CSA Group. 2012b. CSA N288.6-12 Environmental Risk Assessment at Class 1 Nuclear Facilities and Uranium Mines and Mills. Available at http://shop.csa.ca/en/canada/nuclear/n2886-12/invt/27034162012

IAEA (International Atomic Energy Agency). 2009. Classification of Radioactive Waste. General Safety Guide No. GSG-1. November 2009. ISBN: 978-92-0-109209-0.

MNO (Métis Nation of Ontario). 2016. MNO Regions. Available at: http://www.metisnation.org/programs/economic-development/mno-regions/. Accessed August 10, 2016.

MNO. 2004. Métis Nation of Ontario 2004 MNO-MNR Harvesting Agreement Map. Available at: http://www.metisnation.org/registry/harvesting/harvesting-map/. Accessed August 10, 2016.

Nuclear Safety and Control Act. 2016. SC 1997, c 9. Available at: http://laws-lois.justice.gc.ca/PDF/N-28.3.pdf

Species at Risk Act. 2002. SC 2002, c 29. Available at: http://canlii.ca/t/520l0

The Agency (The Canadian Environmental Assessment Agency). 2015a. Operational Policy Statement: Assessing Cumulative Environmental Effects under the *Canadian Environmental Assessment Act, 2012*. March 2015. ISBN: 978-1-100-22263-9.

The Agency. 2015b. Operational Policy Statement: Addressing “Purpose of” and “Alternative Means” under the *Canadian Environmental Assessment Act, 2012*. March 2015. ISBN: 978-1-100-22964-5.

The Agency. 2015c. Operational Policy Statement: Determining Whether a Designated Project is Likely to Cause Significant Adverse Environmental Effects under the *Canadian Environmental Assessment Act, 2012.* November 2015. ISBN: 978-0-660-03642-7.

The Agency. 2015d. Reference Guide Considering Aboriginal Traditional Knowledge in Environmental Assessments Conducted Under the *Canadian Environmental Assessment Act, 2012*. March 2015. ISBN: 978-1-100-22926-3.

The Agency. 2015e. Technical Guidance for Assessing Physical and Cultural Heritage or any Structure, Site or Thing that is of Historical, Archeological, Paleontological or Architectural Significance under the *Canadian Environmental Assessment Act, 2012*. March 2015. ISBN: 978-1-100-24141-8.

The Agency. 2014. Technical Guidance for Assessing Cumulative Environmental Effects under the *Canadian Environmental Assessment Act, 2012*. Draft December 2014. ISBN: 978-1-100-25181-3.

Section 2.0 – Purpose of the Project and Project Alternatives

CNL (Canadian Nuclear Laboratories). 2016a. Near Surface Disposal Facility Site Selection Report. 232-10300-TN-001, Revision 2. April 2016.

CNL. 2016b. Conceptual Safety Philosophy for the Near Surface Disposal Facility. 232-508760-SAB-001. Revision 0. July 2016.

CNSC (Canadian Nuclear Safety Commission). 2010. Decision on the Environmental Assessment Screening Report and amendment of the Chalk River Laboratories Operating Licence to Permit Construction and Operation of the Bulk Material Landfill. CMD-10-H105. 2010 June

CNSC. 2006. Assessing the Long Term Safety of Radioactive Waste Management. Regulatory Guide G-320. December 2006. ISBN: 978-0-662-44692-7.

CNSC. 2004a. Keeping Radiation Exposures and Doses “As Low as Reasonably Achievable (ALARA)”. Revision 1. Regulatory Guide G-129. October 2004. ISBN: 0-662-38407-5.

CNSC. 2004b. Managing Radioactive Waste. Regulatory Policy P-290. July 2004. ISBN: 0-662-37659-5.

Golder (Golder Associates Ltd). 2016. Subsurface Geotechnical Survey of the Proposed Near Surface Disposal Facility at Chalk River Laboratories, Chalk River, Ontario, 232-10180-ASD Revision 1. June 2016.

Golder. 2005. Human Health and Safety Considerations Environmental Effects Assessment Report for the Port Hope Project. LLRWMO-03710-ENA-12009. April 2005.

Golder. 2004. Independent Assessment of Long-Term Management Options for Low and Intermediate Level Wastes at OPG's Western Waste Management Facility. February 2004.

IAEA (International Atomic Energy Agency). 2014. Near Surface Disposal Facilities for Radioactive Waste. Specific Safety Guide SSG-29. March 2014. ISBN: 978–92–0–114313–6

IEAE. 2011. Disposal of Radioactive Waste. Specific Safety Requirements SSR-5. April 2011. ISBN 978-92-0-103010-8

IAEA. 2009. Classification of Radioactive Waste. General Safety Guide No. GSG-1. November 2009. ISBN: 978-92-0-109209-0.

IAEA. 2006. Fundamental Safety Principles, Safety Fundamentals No. SF-1. November 2006. ISBN 92–0–110706–4.

IAEA. 2001. Technical Considerations in the Design of Near Surface Disposal Facilities for Radioactive Waste. IAEA-TECDOC-1256. November 2001.

NWMO (Nuclear Waste Management Organization). 2016. Implementing Adaptive Phased Management 2017 to 2021. Draft for Public Review. August 2016

OECD (Organization for Economic Co-operation and Development). 1999. Low-Level Radioactive Waste Repositories: An Analysis of Costs. 1999. ISBN 92-64-16154-6

OPG. 2011a. OPG's Deep Geological Repository Project for Low & Intermediate Level Waste – Environmental Impact Statement. Volume 1: Main Report. Prepared by Golder Associates Ltd. 00216-REP-07701-00001. March 2011.

OPG. 2011b. OPG's Deep Geological Repository Project Preliminary Safety Report http://www.opg.com/generating-power/nuclear/nuclear-waste-management/Deep-Geologic-Repository/Documents/Submission/14.Preliminary-Safety-Report.pdf

The Agency (The Canadian Environmental Assessment Agency). 2015. Operational Policy Statement: Determining Whether a Designated Project is Likely to Cause Significant Adverse Environmental Effects under the *Canadian Environmental Assessment Act, 2012.* November 2015. ISBN: 978-0-660-03642-7.

The Agency. 2014. Technical Guidance for Assessing Cumulative Environmental Effects under the *Canadian Environmental Assessment Act, 2012*. Draft December 2014. ISBN: 978-1-100-25181-3.

U.S. Congress, Office of Technology Assessment. 1989. Partnerships under Pressure: Managing Commercial Low-Level Radioactive Waste. OTA-O-426 (Washington, DC: U.S. Government Printing Office, November 1989).

Section 3.0 – Project Description

Canada Gazette, Canadian Nuclear Safety Commission - Regulations, Part II, 2000 June 21.

CNL (Canadian Nuclear Laboratories). 2016. Estimated Upper Limit of NSDF Leachate Characteristics Predicted from CRL Groundwater Monitoring Records. 228-508600-114-002

CNSC (Canadian Nuclear Safety Commission). 2012. Regulatory Guide GD-314. Radiation Protection Program Design for the Transport of Nuclear Substances. March 2012. ISBN: 978-1-100-20530-4

CNSC. 2004. Regulatory Policy P-290. Managing Radioactive Waste. July 2004. ISBN: 0-662-37659-5.

CNSC. 2000. Regulatory Guide G-219.Decommissioning Planning for Licensed Activities. June 2000. ISBN: 0-662-29171-9.

CSA Group (Canadian Standards Association Group). 2009. N294-09 Decommissioning of Facilities Containing Nuclear Substances. Available at: http://shop.csa.ca/en/canada/nuclear/n294-09-r2014/invt/27029842009

CSA Group. N288.1-14, Table G-2

Health Canada. 2014. Federal Nuclear Emergency Plan. Part 1: Master Plan, 5th Edition. ISBN: 978-1-100-23135-8.

IAEA (International Atomic Energy Agency). 2012. Regulations for safe transport of Radioactive Material. Specific Safety Requirement No. SSR-6. October 2012.

Nuclear Safety and Control Act, S.C., 1997, c.9. Available at: http://laws-lois.justice.gc.ca/eng/acts/N-28.3/

Ontario Environmental Protection Act, R.S.O. 1990. Available at: https://www.ontario.ca/laws/statute/90e19

OPSS (Ontario Provincial Standard Specification). 2008. OPSS 120, General Specification for Use of Explosives.

Packaging and Transport of Nuclear Substances Regulations, 2015 SOR/2000-208. Available at: http://laws-lois.justice.gc.ca/eng/regulations/sor-2000-208/index.html

Transport Canada Transportation of Dangerous Goods Regulations

Regulation 347 General Waste Management, R.R.O 1990. Available at: https://www.ontario.ca/laws/regulation/900347

US EPA (United States Environmental Protection Agency). 1995. Construction and Demolition Waste Landfills, PB95-208906, 530-R-95-018, Draft Report.

Section 4.0 – Public and Aboriginal Engagement Activities

AECL (Atomic Energy of Canada Limited). 2014. Public Information Program. CW-513530-REPT-001. Revision 1. September 30, 2014.

CRL (Chalk River Laboratories). 2016. Environmental Assessment (and/or Environmental Effects Review). Project Description: Near Surface Disposal Facility at Chalk River Laboratories. CRL-232-509200-ENA-001, Revision 0, March 2016.

CNL. 2016. Aboriginal Engagement Report. 232-513130-REPT-001. Revision 0. August 18, 2016.

CNSC (Canadian Nuclear Safety Commission). 2016. REGDOC-3.2.2. Public and Aboriginal Engagement: Aboriginal Engagement. February 2016. ISBN: 978-0-660-04518-4.

CNSC. 2012. RD/GD-99.3. Public Information and Disclosure. March 2012. ISBN: 978-1-100-20384-3

Section 5.0 – Environmental Assessment

Section 5.1 – Environmental Assessment Methodology

AECL (Atomic Energy of Canada Limited). 2010. Environmental Impact Statement for AECL's National Research Universal Reactor Long-Term Management Project. CRL-509200-ENA-043. Revision 2. September 2010.

Canadian Environmental Assessment Act, 2012. SC 2012, c 19, s 52. Available at: http://canlii.ca/t/51zdg. CNSC (Canadian Nuclear Safety Commission). 2016a. Generic Guidelines for the Preparation of an Environmental Impact Statement pursuant to the Canadian Environmental Assessment Act, 2012. May 2016. ISBN: 978-0-660-05139-0.

CNSC. 2016b. REGDOC-2.9.1. Environmental Protection: Environmental Policy, Assessments and Protection Measures. December 2016. ISBN: 978-0-660-06255-6.

DFO (Fisheries and Oceans Canada). 2013. Fisheries Productivity Investment Policy: A Proponent's Guide to Offsestting. Ottawa, On, Canada. ISBN 978-1-100-22930-0.

Environment Canada. 2016a. Recovery Strategy for the Blanding's Turtle (*Emydoidea blandingii*), Great Lakes / St. Lawrence population, in Canada [Proposed]. *Species at Risk Act* Recovery Strategy Series. Environment Canada, Ottawa. vii+ 49 p.

Holling, C.S. 1992. Cross-scale morphology, geometry, and dynamics of ecosystems. Ecological monographs, volume 62(4).

Levin, S.A. 1992. The problem of pattern and scale in ecology: the Robert H. MacArthur award lecture. Ecology, volume 73(6).

Migratory Birds Convention Act, 1994 (S.C. 1994, c. 22). http://laws-lois.justice.gc.ca/PDF/M-7.01.pdf

The Agency (The Canadian Environmental Assessment Agency). 2015. "Operational Policy Statement Addressing 'Purpose of' and 'Alternative Means' under the *Canadian Environmental Assessment Act, 2012*". March 2015. ISBN: 978-0-660-03642-7.

The Agency. 2014. Technical Guidance for Assessing Cumulative Environmental Effects under the *Canadian Environmental Assessment Act, 2012*. Draft December 2014. ISBN: 978-1-100-25181-3.

Wiens, J.A. 1989. Spatial scaling in ecology. Functional ecology, volume 3(4).

Section 5.2 – Atmospheric Environment

Section 5.2.1 – Air Quality

Alberta Environment and Sustainable Resource Development. 2013. Air Quality Model Guideline – Effective October 1st, 2014. ISBN: 978-1-4601-0599-3.

Brook, J.R., T.F. Dann, and R.T. Burnett. 2011. The Relationship Among TSP, PM10, PM2.5, and Inorganic Constituents of Atmospheric Participate Matter at Multiple Canadian Locations. Journal of the Air & Waste Management Association, volume 47(1).

CCME (Canadian Council of Ministers of the Environment). 2014. Canada-Wide Standards for Particulate Matter and Ozone, 2012 Final Report. ISBN: 978-1-77202-009-0

CCME. 1999. Canadian National Ambient Air Quality Objectives: Process and Status. ISBN: 1-896997-34-1.

CNL (Canadian Nuclear Laboratories). 2016. Annual Safety Report: Effluent Verification Monitoring at Chalk River Laboratories in 2015. CRL-509254-ASR-2015 Revision 0. June 2015.

CNL. 2013. Procedure Management and Monitoring of Emissions Company Wide. CW-509200-PRO-001 Revision 0

CNSC (Canadian Nuclear Safety Commission). 2016. REGDOC-2.9.1. Final Environmental Protection: Environmental Policy, Assessments and Protection Measures. December 2016. ISBN: 978-0-660-06255-6.

Environment and Climate Change Canada (ECCC). 2016. National Pollutant Release Inventory Pollution Data and Reports. http://www.ec.gc.ca/inrp-npri/default.asp?lang=En&n=B85A1846-1

ECCC. 2013. National Air Pollution Surveillance Program (NAPS). http://www.ec.gc.ca/rnspa-naps/Default.asp?lang=En&n=5C0D33CF-1

Government of Canada. 2013. Objectives for Ambient $PM_{2.5}$ and Ozone [Canadian Ambient Air Quality Standards (CAAQS) for $PM_{2.5}$ and Ozone]. Canada Gazette Vol 147, 21.

Health Canada. 1994. National Ambient Air Quality Objectives for Carbon Monoxide. Executive Summary, Desirable, Acceptable and Tolerable Levels. ISBN 0-662-25642-5

MOECC (Ministry of the Environment and Climate Change). 2015. Guideline for Greenhouse Gas Emissions Reporting. PIBs 9906e. December 2015.

MOECC. 2012. Ontario’s Ambient Air Quality Criteria. Standards Development Branch, Ontario Ministry of the Environment. PIBS# 6570e01. April 2012.

MOECC. 2009. Procedure for Preparing an Emission Summary and Dispersion Modelling Report, Version 3.0. PIBS 3614e03. March 2009.

MOECC. 2008. Technical Bulletin: Methodology for Modelling Assessments of Contaminants with 10-minute average standards and guidelines under O. Reg. 419/05. Standards Development Branch, Ontario Ministry of the Environment.

The Agency (Canadian Environmental Assessment Agency). 2014. Technical Guidance for Assessing Cumulative Environmental Effects under the Canadian Environmental Assessment Act, 2012. December 2014. DRAFT.

U.S. EPA (United States Environmental Protection Agency). 2005. 40 CRF Par 51 Revision to the Guideline on air Quality Models: Adoption of a Preferred General Purpose (Flat and Complex Terrain) Dispersion Model and other Revisions. Office of Air Quality Planning and Standards, Emissions Monitoring and Analysis Division, Research Triangle Park, North Carolina.

U.S. EPA. 2004. AERMOD: Description of Model Formulation. EPA-454/R-03-004. Office of Air Quality Planning and Standards, Emissions Monitoring and Analysis Division, Research Triangle Park, North Carolina.

Watson et al. 2000. Reconciling Urban Fugitive Dust Emissions Inventory and Ambient Source Contributions Estimates: Summary of Current Knowledge and Needed Research. Desert Research Institute. Reno, Nevada. pp. 240.

Watson et al. 1996. Effectiveness Demonstration of Fugitive Dust Control Methods for Public Unpaved Roads and Unpaved Shoulders on Paved Roads Final Report. Desert Research Institute. Sacramento, CA.

Section 5.2.2 – Greenhouse Gases

CNL (Canadian Nuclear Laboratories). 2016. Annual Safety Report: Effluent Verification Monitoring at Chalk River Laboratories in 2015. CRL-509254-ASR-2015 Revision 0

CNL. 2013. Procedure Management and Monitoring of Emissions Company Wide. CW-509200-PRO-001 Revision 0

ECCC (Environment and Climate Change Change). 2016. National Inventory Report 1990-2014: Greenhouse Gas Sources and Sinks in Canada. April 2016. ISSN: 2371-1329

ECCC. 2015. Technical Guidance on Reporting of Green House Gas Emissions. November 2015. ISSN: 1719-0487.

IPCC (Intergovernmental Panel on Climate Change). 2006. National Greenhouse Gas Inventory Guidelines – Volume 4: Agriculture, Forestry and Other Land Use; Chapter 4: Forest Land.

ISO (International Organization of Standardization). 2006. ISO 4064-1:2006 Greenhouse gases - Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals. Available at: http://www.iso.org/iso/catalogue_detail?csnumber=38381

MOECC (Ministry of the Environment and Climate Change). 2016. *Ontario Regulation 452/09: Greenhouse Gas Emissions Reporting. Environmental Protection Act*.

MOECC. 2015. Guideline for Greenhouse Gas Emissions Reporting. PIBs 9906e. December 2015.

MOECC. 2014. Greenhouse Gas Emissions Reporting by Facility. Available from: https://www.ontario.ca/data/greenhouse-gas-emissions-reporting-facility

The Agency (Canadian Environmental Assessment Agency). 2014. Technical Guidance for Assessing Cumulative Environmental Effects under the Canadian Environmental Assessment Act, 2012. December 2014. DRAFT.

U.S. EPA (United States Environmental Protection Agency). 2005. Landfill Gas Emissions Model (LandGEM) Version 3.02 User's Guide. EPA-600/R-05/047. Office of Research and Development National Risk Management Research Laboratory, Air Pollution Prevention and Control Division, Research Triangle Park, North Carolina.

Section 5.3 – Geological and Hydrogeological Environment

Section 5.3.1 – Geology

AMEC (AMEC Foster Wheeler). 2017. Multidisciplinary Subsurface Investigation, Phase 2, For the Detailed Design of the Near Surface Disposal Facility Project at Chalk River Laboratories, Chalk River, Ontario, Ref. No. TZ16018 – Phase 2.

AMEC (AMEC Foster Wheeler). 2016. Multidisciplinary Subsurface Investigation For the Detailed Design of the Near Surface Disposal Facility Project at Chalk River Laboratories, Chalk River, Ontario, Ref. No. TZ16018.

CNL (Canadian Nuclear Laboratories). 2016a. Geologic Waste Management Facility Descriptive Geosphere Site Model Report: Phase 1, 361101-10260-REPT-005, Canadian Nuclear Laboratories.

CNL. 2016b. Contaminant Migration from Reactor Pit 2, CRL Legacy Waste Areas, 3613-121221-REPT-003 Revision D1, Canadian Nuclear Laboratories.

CNSC (Canadian Nuclear Safety Commission). 2016. Generic Guidelines for the Preparation of an Environmental Impact Statement pursuant to the *Canadian Environmental Assessment Act, 2012.* ISBN 978-0-660-05139-0

Carr, W.W., Mitchell, W.R., and Watt, W.J. 1991. Basic Soil Interpretations for Forest Development Planning: Surface Soil Erosion and Soil Compaction. BC Ministry of Forests, Victoria, BC.

Catto, N.R., Patterson, R.J., and Gorman, W.A. 1982. The late Quaternary geology of the Chalk River region, Ontario and Quebec. Canadian Journal Earth Sciences, volume 19(6).

Chapman, L.J. and Putnam, D.F. 1984. The Physiography of Southern Ontario, Third Edition. Ontario Geological Survey Special Volume 2. Ontario Ministry of Natural Resources, Toronto, Ontario.

Crins, W.J., Gray, P.A., Uhlig, P.W.C., and Webster, M.C. 2009. The Ecosystems of Ontario, Part 1: Ecozones and Ecoregions. Ontario Ministry of Natural Resources. Science & Information Branch Inventory, Monitoring and Assessment Section. Peterborough, Ontario.

Gendron Resource Surveys Ltd. 1987. Forest Resource Inventory land cover dataset as shown on Chalk River Laboratories Exclusion Area Forest Cover Type Map and Chalk River Laboratories Exclusion Area Forest Cover Species Type Map. Eng. Dwg. Reference # E-4500-33.

Gillespie, J.E., Wicklund, R.E., and Matthews, B.C. 1964. Soil survey of Renfrew County. Ontario Department of Agriculture, Canada Department of Agriculture.

Golder (Golder Associates Ltd.). 2016. Subsurface Geotechnical Survey of the Proposed Near Surface Disposal Facility at Chalk River Laboratories, Chalk River, Ontario, 232-10180-ASD Rev.1.

King, K.J., and Killey, R.W.D. 1994. Quaternary Geology of the AECL Chalk River Laboratories Property: A Review. STF Tech. Bib. No. 345, Sitting Task Force, Low-level Radioactive Waste Management.

MOECC (Ministry of Environment and Climate Change). 2003. Stormwater Management Planning and Design Manual, March 2003. ISBN 0-7794-2969-9, PIBS 4329e, Queen's Printer for Ontario, 2003. https://www.ontario.ca/document/stormwater-management-planning-and-design-manual

MNRF (Ministry of Natural Resources and Forestry). 2016. Land Information Ontario. OHN Waterbody. Available at: https://www.javacoeapp.lrc.gov.on.ca:443/geonetwork?uuid=3ebaf6b2-6dd6-4ebb-a6bb-4fc778426709.

OPSS (Ontario Provincial Standard Specification). 2008. OPSS 120: General Specification for Use of Explosives.

Raven Beck (Raven Beck Environmental Ltd). 1994. Bedrock geological mapping and studies of the Chalk River Laboratories property, Deep River, Ontario, Volume 1 of 2, Siting Task Force Geo-Sci 10, Tech. Bib. No. 338A.

SCWG (Soil Classificaiton Working Group). 1998. The Canadian System of Soil Classification – Third Edition. Agriculture and Agri-Food Canada, Research Branch. ISBN: 0-660-17404-9 .

The Agency (Canadian Environmental Assessment Agency). 2014. Technical Guidance for Assessing Cumulative Environmental Effects under the Canadian Environmental Assessment Act, 2012. December 2014. DRAFT.

Section 5.3.2 – Hydrogeology

AECL (Atomic Energy Canada Limited). 2010. Geochemical and Isotropic Characterization of CRL Boreholes, CRL Geologic Waste Management Facility, 361101-10142-REPT-002 Rev. 0.

AMEC (AMEC Foster Wheeler). 2017. Multidisciplinary Subsurface Investigation, Phase 2, For the Detailed Design of the Near Surface Disposal Facility Project at Chalk River Laboratories, Chalk River, Ontario, Ref. No. TZ16018 – Phase 2.

AMEC. 2016. Multidisciplinary Subsurface Investigation For the Detailed Design of the Near Surface Disposal Facility Project at Chalk River Laboratories, Chalk River, Ontario, Ref. No. TZ16018.

AECOM (AECOM Canada Ltd.). 2016a. Leachate and Wastewater Characterization (Quantity and Quality), Canadian Nuclear Laboratories, Near Surface Disposal Facilities Design and Consulting Services. B1551-508600-REPT-001.

AECOM (AECOM Canada Ltd.). 2016b. Contingency Plan for Leachate, Wastewater, Groundwater, Surface Water and Landfill Gas, Canadian Nuclear Laboratories, Near Surface Disposal Facilities Design and Consulting Services. NSDF-508600-PLA-004.

CNL (Canadian Nuclear Laboratories). 2017. Environmental Background, Limits and Benchmarks for Monitoring Program Design, Risk Assessment and Risk Management Decisions – Chalk River Laboratories. ENVP-509220-REPT-002.

CNL. 2016a. Annual Safety Report, CRL Groundwater Monitoring Program Annual Report for 2014, Chalk River Site Documentation, CRL-509249-ASR-2014 Revision 0, Canadian Nuclear Laboratories.

CNL. 2016b. Contaminant Migration from Reactor Pit 2, CRL Legacy Waste Areas, 3613-121221-REPT-003 Revision D1, Canadian Nuclear Laboratories.

CNL. 2016c. Performance Assessment for Near Surface Disposal Facility to support the Environmental Impact Statement, 232-509240-ASD-001 Revision R0. 2017.

CNL. 2015a. Radiological Contamination in the South Swamp, 1997 to 2011, CRL Waste Management Area's Environmental Remediation, 3611-121250-REPT-005 Revision 0, Canadian Nuclear Laboratories.

CNL. 2015b. Radiological Contamination in the East Swamp, 2002 to 2012. 3611-121250-REPT-006. Revision 0. March 2015.

CNL. 2014. Subsurface Radionuclide Migration from the Chemical Pit, CRL Legacy Waste Areas, 3613-121250-REPT-008 Revision 0, Canadian Nuclear Laboratories.

Golder (Golder Associates Ltd.). 2017. Groundwater Flow Modelling of the Near Surface Disposal Facility, Chalk River, Ontario, 1547525 Draft 1.0.

Golder. 2016. Subsurface Geotechnical Survey of the Proposed Near Surface Disposal Facility at Chalk River Laboratories, Chalk River, Ontario, 232-10180-ASD-001 Rev. 1.

Harbaugh, A.W. 2005. MODFLOW-2005, the U.S. Geological Survey modular ground-water model – the Ground-Water Flow Process: U.S. Geological Survey Techniques and Methods 6-A16.

King-Sharpe, K.J., Frape, S.K., Peterman, Z., Gwynne, R., Tian, L., and Gurban, I. 2016. Synthesis of Geochemical and Fracture Mineral Studies Relevant to a Deep Geological Repository for Nonfuel Wastes at Chalk River, CNL Nuclear Review, 10.12943/CNR.2016.00015, September, 2016.

MOECC (Ministry of the Environment and Climate Change). 2006. Technical Support Document for the Ontario Drinking Water Standards, Objectives and Guidelines, Ontario Ministry of the Environment.

MOECC. 2003. Stormwater Management Planning and Design Manual, March 2003. ISBN 0-7794-2969-9, PIBS 4329e, Queen's Printer for Ontario, 2003. https://www.ontario.ca/document/stormwater-management-planning-and-design-manual

Niswonger, R.G., Panday, S., and Ibaraki, M. 2011. MODFLOW-NWT, A Newton formulation for MODFLOW-2005: U.S. Geological Survey Techniques and Methods 6-A37, 44 p.

Pollock, D.W. 1989. Documentation of a computer program to compute and display pathlines using results from the U.S. Geological Survey modular three-dimensional finite-difference ground-water flow model: U.S. Geological Survey Open-File Report 89–381, 188 p.

Raven Beck Environmental Ltd. 1994. Bedrock geological mapping and studies of the Chalk River Laboratories property, Deep River, Ontario, Volume 1 of 2, Siting Task Force Geo-Sci 10, Tech. Bib. No. 338A.

The Agency. 2014. Technical Guidance for Assessing Cumulative Environmental Effects under the *Canadian Environmental Assessment Act, 2012*. Draft December 2014. ISBN: 978-1-100-25181-3.

Section 5.4 – Surface Water

Section 5.4.1 – Hydrology

AECL (Atomic Energy of Canada Limited). 2010. Environmental Impact Statement for AECL's National Research Universal Reactor Long-Term Management Project Chalk River Site (includes NLBU Administrative Records) CRL-509200-ENA-043. Revision 2.

CNL (Canadian Nuclear Laboratories). 2016a. Perch Creek Catchment Information. CW-511300-FM-001 Rev. 5.

CNL. 2016b. Perch Creek catchment annual flow rates downstream of Perch Lake Outlet (PL0CW-511300-PRO-647).

Golder (Golder Associates Ltd). 2016. Interim Report, Subsurface Geotechnical Survey of the Proposed Near Surface Disposal Facility at Chalk River Laboratories, Ontario.

Golder. 2014. 361104-10180-ASD-002 Subsurface Geotechnical Survey of Proposed VLLW Sites, Atomic Energy of Canada Limited.

Robertson, E., and Barry, P.J. 1985. The water and energy balances of Perch Lake (1969-1980). Atmosphere-Ocean 23(3).

Sowden, T. and Power, G. 1981. The Icthyofauna of the Chalk River Property of Atomic Energy of Canada Limited. University of Waterloo, Waterloo, Ontario.

Yankovich, T.L., Zach, R., King, K.J., Killey, R.W.D., Collins, R., and Dolinar, G.M. 2000. Ecological Risk Assessment for Perch Lake at AECL's Chalk River Laboratories - Present Conditions. Atomic Energy of Canada Limited. Waste Technology Business Unit. Whiteshell Laboratories. Pinawa, Manitoba. Technical Record TR-796.

The Agency (Canadian Environmental Assessment Agency). 2014. Technical Guidance for Assessing Cumulative Environmental Effects under the Canadian Environmental Assessment Act, 2012. December 2014. DRAFT.

Section 5.4.2 – Surface Water Quality

AECOM (AECOM Canada Ltd). 2016. 60% Design Deliverable for Leachate and Wastewater Characterization. Deliverable 1.25, Revision B, B1551-508600-REPT-001.

AECOM. 2016. 60% Design Deliverable for WWTP Process Design. Deliverable 1.16, Revision A, B1551-508233-REPT.

AECL (Atomic Energy of Canada Limited). 2010. Environmental Impact Statement for AECL's National Research Universal Reactor Long-Term Management Project Chalk River Site (includes NLBU Administrative Records) CRL-509200-ENA-043. Revision 2.

AECL. 2008. Environmental Assessment-Chalk River Laboratories: A Description of the Environmental Baseline for Environmental Assessments –Safety and Environmental Analysis Branch. CRL-509200-ENA-001 NSN-533. Revision 2.

CNL (Canadian Nuclear Laboratories). 2016a. Annual Safety Report – Environmental Monitoring in 2015 at Chalk River Laboratories CRL-509243-ASR-2015. Revision 0.

CNL. 2016b. Perch Creek catchment annual flow rates downstream of Perch Lake Outlet (PL0CW-511300-PRO-647).

CRL (Chalk River Laboratories). 2013. Environmental Risk Assessment of Chalk River Laboratories – 2012. ENVP-509220-REPT-001.

EcoMetrix Inc. 2005. Ecological Effects Review of Chalk River Laboratories. CRL-509000-REPT-001.

Fisheries and Oceans Canada (DFO). 2016. Measures to Avoid Causing Harm to Fish and Fish Habitat including Aquatic Species at Risk. [Accessed February 2017]. http://www.dfo-mpo.gc.ca/pnw-ppe/measures-mesures/measures-mesures-eng.html

MOECC (Ministry of the Environment and Climate Change). 2003. Municipal-Industrial Strategy for Abatement (MISA): a policy and program statement of the Government of Ontario on controlling municipal and industrial discharges into surface waters.

Robertson, E., and Barry, P.J. 1985. The water and energy balances of Perch Lake (1969-1980). Atmosphere-Ocean 23(3).

The Agency (Canadian Environmental Assessment Agency). 2014. Technical Guidance for Assessing Cumulative Environmental Effects under the Canadian Environmental Assessment Act, 2012. December 2014. DRAFT.

Wright D.G. and Hopky, G.E. 1998. Guidelines for the use of explosives in or near Canadian fisheries waters. Canadian technical report of fisheries and aquatic sciences 2107. DFO, Winnipeg, MB, Canada.

Yankovich, T.L., Zach, R., King, K.J., Killey, R.W.D., Collins, R., and Dolinar, G.M. 2000. Ecological Risk Assessment for Perch Lake at AECL's Chalk River Laboratories - Present Conditions. Atomic Energy of Canada Limited. Waste Technology Business Unit. Whiteshell Laboratories. Pinawa, Manitoba. Technical Record TR-796.

Section 5.5 – Aquatic Environment

CG&S. 1998. An Environmental Study for Waste Management Area "A" at AECL Chalk River Laboratories. Prepared for Atomic Energy of Canada Limited. 85 pp.

CG&S. 1997. An Environmental Baseline Study for Waste Management Areas "B" and "C" at AECL Chalk River Laboratories. Prepared for Atomic Energy of Canada Limited. 93 pp.

CNL (Canadian Nuclear Laboratories). 2017. Performance Assessment for Near Surface Disposal Facility to support the Environmental Impact Statement, 232-509240-ASD-001 Revision R0.

CNL. 2016. Environmental Monitoring in 2015 at Chalk River Laboratories. CRL-509243-ASR-2015. Canadian Nuclear Laboratories, Chalk River, Ontario

CNL. 2015. Environmental Monitoring in 2014 at Chalk River Laboratories. CRL-509243-ASR-2014. Canadian Nuclear Laboratories, Chalk River, Ontario.

DFO (Fisheries and Oceans Canada). 2013. Fisheries Productivity Investment Policy: A Proponent's Guide to Offsestting. Ottawa, On, Canada. ISBN 978-1-100-22930-0.

Government of Canada. 2016. Aquatic Species Listed under SARA and Protected by the Fisheries Act. http://registrelep-sararegistry.gc.ca/. Accessed March 16, 2017.

MOE (Ontario Ministry of the Environment). 2003. Stormwater Management Planning and Design Manual, March 2003. ISBN 0-7794-2969-9, PIBS 4329e, Queen's Printer for Ontario, 2003. Available at: https://www.ontario.ca/document/stormwater-management-planning-and-design-manual.

Ophel, I. L. and Fraser, C.D. 1971. The fate of Cobalt-60 in a natural freshwater ecosystem. In: Radionucleotides in ecosystems. CONF-710501.

OPS (Ontario Provincial Standards). 2014. Ontario Provincial Standard Specification, Metric OPSS.Prov 120 November 2014, General Specification for the Use of Explosives. Ontario Provincial Standards, Toronto, ON. 10 pp. Available from: http://www.raqsa.mto.gov.on.ca/techpubs/ops.nsf/0/a97b9868eb1f53028525808200629106/$FILE/OPSS.PROV%20120%20Nov2014.pdf

Reed, D.H., O'Grady, J.J., Brook, B.W., Ballou, J.D., and Frankham, R. 2003. Estimates of minimum viable population sizes for vertebrates and factors influencing those estimates. Biological Conservation 113:23-34.

Robertson, E. and Barry, P.J. 1985. The water and energy balances of Perch Lake (1969–1980), Atmosphere Ocean 23: 238-253, DOI: 10.1080/07055900.1985.9649227

Scott, W.B. and Crossman, E.J. 1973. Freshwater Fishes of Canada. Fisheries Research Board of Canada.

Sowden, T. and Power, G. 1981. The Icthyofauna of the Chalk River Property of Atomic Energy of Canada Limited. University of Waterloo, Waterloo, Ontario. 158 pp.

The Agency (The Canadian Environmental Assessment Agency). 2014. Technical Guidance for Assessing Cumulative Environmental Effects under the *Canadian Environmental Assessment Act, 2012*. Draft December 2014. ISBN: 978-1-100-25181-3.

Wright, D.G. 1982. A discussion paper on the effects of explosives on fish and marine mammals in the waters of the Northwest Territories. Can. Tech. Rep. Fish. Aquat. Sci. 1052: v + 16 p.

Wright, D.G. and Hopky, G.E. 1998. Guidelines for the use of explosives in or near Canadian fisheries waters. Can. Tech. Rep. Fish. Aquat. Sci. 2107: iv + 34 p.

Yankovich, TL, Zach, R., King, K.J, Killey, R.W.D, Collins, R., and Dolinar, G.M. 2000. Ecological risk assessment for Perch Lake at AECL's Chalk River Laboratories – Present Conditions. Atomic Energy of Canada Limited, Pinawa, MB, Technical TR-76. 153 pp.

Section 5.6 – Terrestrial Environment

AECL (Atomic Energy of Canada Limited). 2014a. Preliminary Decommissioning Plan. CPDP-508300-PDP-001. Revision 2. Atomic Energy of Canada Limited, Chalk River, ON. 88 pp.

AECL. 2014b. Report, General: 2013 Species at Risk Annual Report. CRL-509213-REPT-005. Revision 0. Atomic Energy of Canada Limited, Chalk River, ON. 127 pp.

AECL. 2013a. Report, General: 2012 Species at Risk Annual Report. CRL-509213-REPT-004. Revision 0. Atomic Energy of Canada Limited, Chalk River, ON. 81 pp.

AECL. 2013b. Safety analysis basis CRL site characteristics. CRL-03510-SAB-001 Revision 3. 83 pp.

AECL. 2013c. Management and Monitoring of Emissions. CW-509200-PRO-001. 65 pp.

AECL. 2008. Chalk River Laboratories: A description of the environmental baseline for environmental assessments. CRL-509200-ENA-001 Revision 2. Atomic Energy of Canada Limited, Chalk River, ON. 111 pp.

AECL. 2010. Environmental Impact Statement for AECL's National Research Universal Reactor Long-term Management Project. Prepared by SENES Consultants Limited. 496 pp.

AECOM. 2016. Canadian Nuclear Laboratories: Near Surface Disposal Facility Design and Consulting Services – Closure Plan. Deliverable 14.5, Revision A. Prepared for CNL, Chalk River, ON. Prepared by AECOM Canada Ltd., Markham, ON. 20 pp.

Alaback, P.B. 1982. Dynamics of Understory Biomass in Sitka Spruce-Western Hemlock Forests of Southeast Alaska. Ecology 63:1932-1948.

Askins, R.A. 1994. Open Corridors in a Heavily Forested Landscape: Impact on Shrubland and Forest-interior Birds. Wildlife Society Bulletin 22:339-347.

Askins, R.A. and Philbrick, M.J. 1987. Effect of Changes in Regional Forest Abundance on the Decline and Recovery of a Forest Bird Community. Wilson Bulletin 99(7): 21.

Auerback, N.A., Walker, M.D., and Walker, D.A. 1997. Effects of Roadside Disturbance on Substrate and Vegetation Properties in Arctic Tundra. Ecological Applications 7:218-235.

Ball, J.R. and Bayne, E.M. 2014. Status of Canada Warbler (*Cardellina canadensis*) in Alberta. Alberta Wildlife Status Report No. 70. Prepared for Alberta Environment and Sustainable Resource Development (ESRD) and Alberta Conservation Association (ACA).

Baxter, A.T., and Allan, J.R. 2008. Use of Lethal Control to Reduce Habituation to Blank Rounds by Scavenging Birds. Journal of Wildlife Management 72:1653-1657.

BBOP (Business and Biodiversity Offset Programme). 2015. Mitigation Hierarchy. [Accessed October 2016]. http://bbop.forest-trends.org/pages/mitigation_hierarchy.

Beaudry, F., Pidgeon, A.M., Radeloff, V.C., Howe, R.W., Mladenoff, D.J., and Bartelt, G.A. 2010. Modeling Regional-scale Habitat of Forest Birds when Land Management Guidelines are Needed but Information Is Limited. Biological Conservation 143:1759-1769.

Beckmann, J.P. and Lackey, C.W. 2008. Carnivores, Urban Landscapes, and Longitudinal Studies: a Case History of Black Bears. Human-Wildlife Conflicts 2:168-174.

Benn, B. and Herrero, S. 2002. Grizzly Bear Mortality and Human Access in Banff and Yoho National Parks, 1971-98. Ursus 13:213-221.

Bladon, K.D., Emelko, M.B., Silins, U., and Stone, M. 2014. Wildfire and the Future of Water Supply. Environmental Science & Technology 48:8936-8943.

Blancher, P.J., Phoenix, R.D., Badzinski, D.S., Cadman, M.D., Crewe, T.L., Downes, C.M., Fillman, D., Francis, C.M., Hughes, J., Hussell, D.J., and Lepage, D. 2009. Population trend status of Ontario's forest birds. The Forestry Chronicle 85:184-201.

Bohning Gaese, K., Taper, M.L., and Brown, J.H. 1993. Are Declines in North American Insectivorous Songbirds Due to Causes on the Breeding Range? Conservation Biology 7:76 86.

Both, C., Van Turnhout, C.A., Bijlsma, R.G., Siepel, H., Van Strien, A.J., and Foppen, R.P. 2009. Avian Population Consequences of Climate Change are Most Severe for Long-distance Migrants in Seasonal Habitats. Proceedings of the Royal Society B: Biological Sciences 277:1259-1266.

Broders, H. G., Forbes, G.J., Woodley, S., and Thompson, I.D. 2006. Range Extent and Stand Selection for Roosting and Foraging in Forest-dwelling Northern Long-Eared Bats and Little Brown Bats in the Greater Fundy Ecosystem, New Brunswick. The Journal of Wildlife Management 70(5):1174-1184.

Broders, H. G. and G. J. Forbes. 2004. Interspecific and intersexual variation in roost-site selection of northern long-eared and little brown bats in the Greater Fundy National Park ecosystem. Journal of Wildlife Management 68: 602-610.

Bushman, E.S. and Therres, G.D.. 1988. Habitat Management Guidelines for Forest Interior Breeding Birds of Coastal Maryland. Maryland Department of Natural Resources, Forest, Park and Wildlife Service. Wildlife Technical Publication 88(1):54.

Cadman, M. D., Sutherland, D.A., Beck, G.G., LePage, D., and Couturier, A.R. 2007. Atlas of the Breeding Birds of Ontario, 2001-2005. Bird Studies Canada, Environment Canada, Ontario Field Ornithologists, Ontario Ministry of Natural Resources, and Ontario Nature, Toronto. xxii + 706 p.

Cadman, M. D., Sutherland, D. A., and Helleiner, F.M. 1987. Atlas of the Breeding Birds of Ontario. University of Waterloo Press. Waterloo, Ontario. 617 p.

California Department of Transportation. 2016. Technical Guidance for the Assessment and Mitigation of the Effects of Traffic Noise and Road Construction Noise on Bats. Contract 43A0306. Sacramento, CA. Prepared by ICF International, Sacramento, CA and West Ecosystems Analysis, Inc., Davis, CA. 75 p. + appendices.

CEAA (*Canadian Environmental Assessment Act, 2012*). SC 2012, c 19, s 52. http://canlii.ca/t/51zdg

Canter, L. and Ross, B. 2010. State of Practice of Cumulative Effects Assessment and Management: The Good, the Bad and the Ugly. Impact Assessment and Project Appraisal 28:261–268.

Carlson, M.L. and Shephard, M. 2007. Is the spread of non-native plants in Alaska accelerating? Meeting the challenge: invasive plants in Pacific Northwest ecosystems. General Technical Report. Harrington TBR, Sarah H. Portland, OR, USA. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 16p..

Chalfoun, A.D., Ratnaswamy, M.J., and Thompson, F.R. 2002. Songbird Nest Predators in Forest–Pasture Edge and Forest Interior in a Fragmented Landscape. Ecological Applications 12:858-867.

Cink, C.L. 2002. Eastern Whip-poor-will (*Antrostomus vociferus*), The Birds of North America (Rodewald, P.G., Ed.). Ithaca: Cornell Lab of Ornithology. https://birdsna.org/Species-Account/bna/species/whip-p1

Clark, J. 2003. Invasive Plant Prevention Guidelines. Centre for Invasive Plant Management. Bozeman, Montana, USA, 15 p.

CNL (Canadian Nuclear Laboratories). 2016a. Report, General: 2015 Species at Risk Annual Report. CRL-509213-REPT-007. Revision 0. Canadian Nuclear Laboratories, Chalk River, ON. 100 p.

CNL. 2017. Performance Assessment for Near Surface Disposal Facility to support the Environmental Impact Statement, 232-509240-ASD-001 Revision R0.

CNL. 2016b. Report, General: Biodiversity Review in for the Near Surface Disposal Facility Project, Near Surface Disposal Facility (NSDF) Project. 232-509213-REPT-001. Revision D1. Canadian Nuclear Laboratories, Chalk River, ON. 57 p.

CNL. 2015a. Report, General: 2014 Species at Risk Annual Report. CRL-509213-REPT-006. Revision 0. Canadian Nuclear Laboratories, Chalk River, ON. 95 p.

CNL. 2015b. Procedure: Management of Land, Habitat and Wildlife. CW-509200-PRO-588. Revision 1. Canadian Nuclear Laboratories, Chalk River, ON. 46 p.

CNSC (Canadian Nuclear Safety Commission). 2015. REGDOC-2.9.1 Draft Environmental Policy, Assessments and Protection Measures. Draft November 2015.

Collins, S.L., James, F.C., and Risser, P.G. 1982. Habitat Relationships of Wood Warblers (Parulidae) in Northern Central Minnesota. Oikos 39:50-58.

Confer, J.L. and Knapp, K. 1981. Golden-winged Warblers and Blue-winged Warblers: The Relative Success of a Habitat Specialist and a Generalist. Auk 98:108-114.

Confer, J.L., P. Hartman, P., and A. Roth, A. 2011. Golden-winged Warbler (*Vermivora chrysoptera*), The Birds of North America (Rodewald, P.G., Ed.). Ithaca: Cornell Lab of Ornithology. https://birdsna.org/Species-Account/bna/species/gowwar

Congdon, J.D., A.E. Dunham, A.E., and R.C. van Loben Sels, R.C. 1993. Delayed Sexual Maturity and Demographics of Blanding's Turtles (Emydoidea blandingii): Implications for Conservation and Management of Long-lived Organisms. Conservation Biology 7:826-833.

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2013. COSEWIC assessment and status report on the little brown myotis *Myotis lucifugus*, northern myotis *Myotis septentrionalis*, Tri-colored bat *Perimyotis subflavus* in Canada – 2013. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xxiv + 93 p.

COSEWIC. 2009. COSEWIC Assessment and Status Report on the Whip-poor-will *Caprimulgus vociferus* in Canada. vi + 28 p.

COSEWIC. 2008. COSEWIC Assessment and Status Report on the Canada Warbler *Wilsonia canadensis* in Canada. vi + 35 p.

COSEWIC. 2006. COSEWIC Assessment and Status Report on the Golden-winged Warbler *Vermivora chrysoptera* in Canada. vii + 30 p.

COSEWIC. 2005. COSEWIC Assessment and Update Status Report on the Blanding's Turtle *Emydoidea blandingii* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. viii + 40 p.

Crampton, L.H. and Barclay, R.M. 1998. Selection of Roosting and Foraging Habitat by Bats in Different-aged Aspen Mixedwood Stands. Conservation Biology 12:1347-1358.

CWS (Canadian Wildlife Service). 2007. Preventing Wildlife Attraction to Northern Industrial Sites. Environment Canada. 30 p.

Dawson, T.P., Jackson, S.T., House, J.I., Prentice, I.C., and Mace, G.M. 2011. Beyond Predictions: Biodiversity Conservation in a Changing Climate. Science. 332(6025):53-58.

Deser, C., Phillips, A., Bourdette, V., and Teng, H. 2010. Uncertainty in Climate Change Projections: The Role of Internal Variability. Climate Dynamics 38 (3-4):527-546.

Desrochers, A. and Hannon, S.J. 1997. Gap Crossing Decisions by Forest Songbirds during the Post-fledging Period. Conservation Biology 11:1204-1210.

eBird. 2016. Species Maps. [Accessed 25 August 2016]. http://ebird.org/ebird/map/.

Ecometrix (Ecometrix Incorporated). 2013. Report, General, Environmental Risk Assessment of Chalk River Laboratories – 2012. Environmental Protection. ENVP-509220-REPT-001. Prepared for AECL Chalk River Laboratories, Chalk River Ontario. Prepared by Ecometrix Incorporated, Mississauga, ON. 358 p.

Environment Canada. 2010. Recovery Strategy for the Butternut (*Juglans cinerea*) in Canada. Species at Risk Act Recovery Strategy Series. Environment Canada, Ottawa. vii + 24 p.

Environment Canada. 2014. Bird Conservation Strategy for Bird Conservation Region 12 in Ontario and Manitoba: boreal hardwood transition – abridged version. 32 p.

Environment Canada. 2015a. Recovery Strategy for the Eastern Whip-poor-will (*Antostromus vociferus*) in Canada [Proposed]. *Species at Risk Act* Recovery Strategy Series. Environment Canada, Ottawa. v + 59 p.

Environment Canada. 2015b. Recovery Strategy for Little Brown Myotis (*Myotis lucifugus*), Northern Myotis (*Myotis septentrionalis*), and Tri-colored Bat (*Perimyotis subflavus*) in Canada [Proposed]. *Species at Risk Act* Recovery Strategy Series. Environment Canada, Ottawa. ix + 110 p.

Environment Canada. 2015c. Federal Land Managers and the Emergency Listing Order for Little Brown Myotis (*Myotis lucifugus*), the Northern Myotis (*Myotis septentrionalis*) and the Tri-colored bat (*Perimyotis subflavus*). Environment Canada, Ottawa. 5 p.

Environment Canada. 2016a. Recovery Strategy for the Blanding's Turtle (*Emydoidea blandingii*), Great Lakes / St. Lawrence population, in Canada [Proposed]. *Species at Risk Act* Recovery Strategy Series. Environment Canada, Ottawa. vii+ 49 p.

Environment Canada. 2016b. Recovery strategy for the Canada warbler (*Cardellina canadensis*) in Canada. *Species at Risk Act* Recovery Strategy Series. Environment Canada, Ottawa. vii + 56 p.

ECCC (Environment and Climate Change Canada). 2016a. Buffer Zone and Setback Distances. [Accessed October 2016]. https://www.ec.gc.ca/paom--itmb/default.asp?lang=En&n=8D910CAC--1.

ECCC. 2016b. General Nesting Periods of Migratory Birds in Canada. [Accessed October 2016]. https://www.ec.gc.ca/paom-itmb/default.asp?lang=En&n=4F39A78F-1%20-%20_fig03_1.

ECCC. 2016c. Recovery Strategy for the Golden-winged Warbler (*Vermivora chrysoptera*) in Canada. Species at Risk Act Recovery Strategy Series. vii + 59 p.

Ethier, K. and Fahrig, L. 2011. Positive Effects of Forest Fragmentation, Independent of Forest Amount, on Bat Abundance in Eastern Ontario, Canada. Landscape Ecology 26(6):865-876.

Fahrig, L. 2001. How Much Habitat is Enough? Biological Conservation 100:65-74.

Fahrig, L. and Rytwinski, T. 2009. Effects of Roads on Animal Abundance: An Empirical Review and Synthesis. [Accessed 10 July 2012]. Ecology and Society 14:21. http://www.ecologyandsociety.org/vol14/iss1/art21/.

Farmer, A.M. 1993. The Effects of Dust on Vegetation – A Review. Environmental Pollution 79:63-75.

Gibbs J.P. and Shriver W.G. 2002. Estimating the Effects of Road Mortality on Turtle Populations. Conservation Biology 16:1647–1652.

Gill, F.B., Canterbury, R.A., and Confer, J.L. 2001. Blue-winged Warbler (*Vermivora cyanoptera*), The Birds of North America (P. G. Rodewald, Ed.). Ithaca: Cornell Lab of Ornithology. https://birdsna.org/Species-Account/bna/species/buwwar

Government of Canada. 2002. *Species at Risk Act*. S.C. 2002, c 29. Ottawa, ON: Minister of Justice. http://canlii.ca/t/520l0

Government of Ontario. 2015a. Canada warbler. [Accessed 26 August 2016]. https://www.ontario.ca/page/canada-warbler.

Government of Ontario. 2015b. Eastern Whip-poor-will. [Accessed 26 August 2016]. https://www.ontario.ca/page/eastern-whip-poor-will.

Government of Canada. 2016. Species at Risk Public Registry - A to Z Species Index. [Accessed August 2016]. http://www.sararegistry.gc.ca/sar/index/default_e.cfm.

Government of Canada. 2002. *Species at Risk Act* (S.C. 2002, c. 29). Current to December 31, 2016. Department of Justice Canada, Government of Canada, Ottawa, ON.

Graham, D. 1987. Brown-headed Cowbird. In: Cadman, M.D., Eagles, P.F.J., and Helleiner, F.M. (eds.). Atlas of the Breeding Birds of Ontario. University of Waterloo Press, Waterloo, Ontario. p. 482-483.

Granger T., Hruby, T., McMillan, A., Peters, D., Rubey, J., Sheldon, D., Stanley, S., and Stockdale, E. 2005. Wetlands in Washington State. Vol. 2, Protecting and Managing Wetlands. Appendix 8-A - An Overview of Ways to Protect and Manage Wetlands. Publication #05-06-008. Washington State Department of Ecology, Olympia, WA. http://www.ecy.wa.gov/programs/sea/wetlands/bas/vol2final/Appendix%208-A_Volume%202_.pdf

Grantz, D.A., Gamer, J.H.B., and Johnson, D.W. 2003. Ecological Effects of Particulate Matter. Environment International, 213-239.

Gregoire, P. (Environment Canada). 2013. Personal communication with Brock Simons (Golder) on 4 December 2013.

Hallworth, M., Ueland, A., Anderson, E., Lambert, J.D., and Reitsma, L.. 2008. Habitat selection and site fidelity of Canada warblers (*Wilsonia canadensis*) in central New Hampshire. Auk 125:880-888.

Hels, T. and Buchwald, E.. 2001. The Effect of Road Kills on Amphibian Populations. *In* Proceedings of the 2001 International Conference on Ecology and Transportation. Irwin, C.L., Garrett, P., and McDermott, K.P. (eds.). Center for Transportation and the Environment, North Carolina State University, Raleigh, NC. p. 25-42.

Hobson, K.A. and Bayne, E.. 2000. Breeding bird communities in boreal forest of western Canada: consequences of “unmixing” the mixedwoods. Condor 102: 759 769.

Huff, A. and Thomas, A.. 2014. Lake Superior Climate Change Impacts and Adaptation. Prepared for Lake Superior Lakewide Action and Management Plan – Superior Work Group. https://www.epa.gov/sites/production/files/2015-11/documents/lake-superior-climate-change-impacts-report-201401-139pp.pdf.

Jantzen, M.K. and Fenton, M.B. 2013. The depth of edge influence among insectivorous bats at forest-field interfaces. Canadian Journal of Zoology 91:287-292.

Jung, T.S., Thompson, I.D., Titman, R.D., and Applejohn, A.P. 1999. Habitat selection by forest bats in relation to mixedwood stand types and structure in central Ontario. Journal of Wildlife Management 63(2):1306-1319.

Kalcounis, M.C. and Brigham, R.M. 1995. Intraspecific variation in wing loading affects habitat use by little brown bats (*Myotis lucifugus*). Canadian Journal of Zoology 73:89-95.

Kristan, W.B. III. and Boarman, W.I. 2007. Effects of anthropogenic development on common raven nesting biology in the west Mojave Desert. Ecological Applications 17:1703-1713.

Lacki, M.J., Hayes, J.P., and Kurta, A. 2007. Bats in Forests: Conservation and Management. Johns Hopkins University Press. 329 p.

Lafortezza, R., Coomes, D., Kapos, V., and Ewers, R. 2010. Assessing the Impacts of Fragmentation on Plant Communities in New Zealand: Scaling from Survey Plots to Landscapes. Global Ecology and Biogeography 19:741-754.

Liebezeit, J.R., Kendall, S.J., Brown, S., Johnson, C.B., Martin, P., McDonald, T.L., Payer, D.C., Rea, C.L., Streever, B., Wildman, A.M., and Zack, S. 2009. Influence of human development and predators on nest survival of tundra birds, Arctic Coastal Plain, Alaska. Ecological Applications 19:1628-1644.

Lowther, P.E. 1993. Brown-headed Cowbird (*Molothrus ater*). The Birds of North America Online (Poole, A., Ed.). Ithaca: Cornell Lab of Ornithology. doi: 10.2173/bna.47.

Machtans, C.S. 2006. Songbird response to seismic lines in the western boreal forest: a manipulative experiment. Canadian Journal of Zoology 84:1421-1430.

Mack, R.N., Simberloff, D., Lonsdale, W.M.,Evans, H., Clout, M., and Bazzaz, F.A. 2000. Biotic Invasions: Causes, Epidemiology, Global Consequences, and Control. Ecological Applications 10:689-710.

Mackay, R.L. and R.M.R. Barclay. 1989. The influence of physical clutter and noise on the activity of bats over water. Can. J. Zool. 67: 1167-1170Marzluff, J.M., and Neatherlin, E. 2006. Corvid response to human settlements and campgrounds: Causes, consequences, and challenges for conservation. Biological Conservation 30:301-314.

MBCA (*Migratory Birds Convention Act*) (1994, c. 22). http://laws-lois.justice.gc.ca/PDF/M-7.01.pdf

McCold, L.N. and Saulsbury, J.W. 1996. Including past and present impacts in cumulative impact assessments. Environmental Management 20:767-776.

McKenzie, D., Halpern, C.B., and Nelson, C.R. 2000. Overstory influences on herb and shrub communities in mature forests of western Washington, U.S.A. Canadian Journal of Forest Research 30:1655-1666.

Monda, M.J., Ratti, J.T., and McCabe, T.R. 1994. Reproductive ecology of tundra swans on the Arctic National Wildlife Refuge, Alaska. Journal of Wildlife Management 58:757-773.

Morris, A.D., Miller, D.A., and Kalcounis-Rueppell, M.C. 2010. Use of forest edges by bats in a managed pine forest landscape. Journal of Wildlife Management 74:26-34.NABCIC (North American Bird Conservation Initiative Canada). 2012. The State of Canada's Birds, 2012. Environment Canada, Ottawa, ON. 36 p.

NABCIC (North American Bird Conservation Initiative Canada). 2012. The State of Canada's Birds, 2012. Environment Canada, Ottawa, ON. 36 pp.NRCan (Natural Resources Canada). 2016. Glossary – Forest Ecology. NRCan, Ottawa, ON. [Accessed 19 October 2016]. https://cfs.nrcan.gc.ca/terms/category/20.

Nebel, S., Mills, A., McCracken, J.D., and Taylor, P.D. 2010. Declines of aerial insectivores in North America follow a geographic gradient. Avian Conservation and Ecology 5:1 [Accessed 5 July 2016]. http://www.ace eco.org/vol5/iss2/art1/.

Nicholson, E., Westphal, M.I., Frank, K., Rochester, W.A., Pressey, R.L., Lindenmayer, D.B., and Possingham, H.P. 2006. A new method for conservation planning for the persistence of multiple species. Ecology Letters 9:1049-1060.

Nituch, L.A. and Bowman, J. 2013. Community-level effects of climate change on Ontario's terrestrial biodiversity. Climate Change Research Report-Ontario Forest Research Institute (CCRR-36). https://dr6j45jk9xcmk.cloudfront.net/documents/2693/ccrr-36-aoda-feb-2014.pdf.

Nocera, J.J., Blais, J.M., Beresford, D.V., Finity, L.K., Grooms, C., Kimpe, L.E., Kyser, K., Michelutti, N., Reudink, M.W., and Smol, J.P. 2012. Historical pesticide applications coincided with an altered diet of aerially foraging insectivorous chimney swifts. Proceedings of the Royal Society B, Biological Sciences. [Accessed 5 July 2016]. http://rspb.royalsocietypublishing.org/content/royprsb/early/2012/04/15/rspb.2012.0445.full.pdf.

Norton, M.R. and Hannon, S.J. 1997. Songbird response to partial cut logging in the boreal mixedwood forest of Alberta. Canadian Journal of Forest Research 27:44-53.

Norton, M.R., Hannon, S.J., and Schmiegelow, F.K.A. 2000. Fragments are not islands: patch vs. landscape perspective on songbird presence and abundance in a harvested boreal forest. Ecography 23: 209-223.Noss, R.F. 1990. Indicators for monitoring biodiversity: A hierarchical approach. Conservation Biology, 4:355-364.

Olson, C.R. and Barclay, R.M.R. 2013. Concurrent changes in group size and roost use by reproductive female Little Brown Bats (*Myotis lucifugus*). Canadian Journal of Zoology 91:149-155.

OMNR (Ontario Ministry of Natural Resources). 2000. Significant Wildlife Habitat Technical Guide.

OMNR. 2007. Ecological Land Classification Primer – Central and Southern Ontario. Toronto, ON: Queen’s Printer for Ontario. http://www.ontla.on.ca/library/repository/mon/17000/271899.pdf

OMNR. 2009. Forest Information Manual 2009 – Forest Resource Inventory Technical Specifications 2009. Toronto, ON: Queen’s Printer for Ontario. 93 p. https://www.ontario.ca/document/forest-resources-inventory-technical-specifications.

OMNR. 2010a. Forest Management Guide for Great Lakes - St. Lawrence Forests. Toronto, ON: Queen’s Printer for Ontario. 57 p.

OMNR. 2010b. Forest Management Guide for Conserving Biodiversity at the Stand and Site Scales. Toronto, ON: Queen’s Printer for Ontario. 211 p.

OMNR. 2012a. General habitat description for the eastern whip poor will (*Caprimulgus vociferus*). 4 p. http://files.ontario.ca/environment and energy/species at risk/mnr_sar_ghd_whp_pr_wll_en.pdf.

OMNR. 2012b. Survey Protocol for Blanding’s Turtle (*Emydoidea blandingii*) in Ontario. Ontario Ministry of Natural Resources, Peterborough, Ontario. ii + 14 p.

OMNRF (Ontario Ministry of Natural Resources and Forestry). 2016a. Land Information Ontario spatial data warehouse. https://www.javacoeapp.lrc.gov.on.ca/geonetwork/srv/en/main.home

OMNRF. 2016b. Natural Heritage Information Centre – Make-a-Map: Natural Heritage Areas. Spatial query conducted 19 August 2016. https://www.ontario.ca/page/make-natural-heritage-area-map

OPS (Ontario Provincial Standards). 2014. Ontario Provincial Standard Specification, Metric OPSS.Prov 120 November 2014, General Specification for the Use of Explosives. Ontario Provincial Standards, Toronto, ON. 10 pp. Available from: http://www.raqsa.mto.gov.on.ca/techpubs/ops.nsf/0/a97b9868eb1f53028525808200629106/$FILE/OPSS.PROV%20120%20Nov2014.pdf

Ortega, C.P. 2012. Chapter 2: Effects of noise pollution on birds. Ornithological Monographs 74:6-22.

Paquette, S.R., Pelletier, F., Garant, D., and Belisle, M. 2014. Severe recent decrease of adult body mass in a declining insectivorous bird population. Proceedings of the Royal Society B, Biological Sciences 281:20140649. http://rspb.royalsocietypublishing.org/content/royprsb/281/1786/20140649.full.pdf.

Parendes L.A. and Jones, J.A. 2000. Role of light availability and dispersal in exotic plant invasion along roads and streams in the H.J. Andrews Experimental Forest, Oregon. Conservation Biology 14:64-75.

Peachey, C.J., Sinnett, D., Wilkinson, M., Morgan, G.W., Freer-Smith, P.H., and Hutchings, T.R. 2009. Deposition and solubility of airborne metals to four plant species grown at varying distances from two heavily trafficked roads in London. Environmental pollution 157:2291-2299.

Peirce, K.N., and Van Daele, L.J. 2006. Use of a garbage dump by brown bears in Dillingham, Alaska. Ursus 17:165-177.

Polster DF. 2005. The role of invasive plant species management in mined land reclamation. Can Reclam Summer/Fall: p. 24-32.

Reed, D.H., O'Grady, J.J., Brook, B.W., Ballou, J.D., and Frankham, R. 2003. Estimates of minimum viable population sizes for vertebrates and factors influencing those estimates. Biological Conservation 113:23-34.

Reichard, S.H. and White, P. 2001. Horticulture as a Pathway of Invasive Plant Introductions in the United States. Bioscience 51:103-113.

Regulation Respecting Standards of Forest Management for Forests in the Domain of the State. c. A-18.1, r. 7. http://legisquebec.gouv.qc.ca/en/ShowDoc/cr/A-18.1,%20r.%207

Restani, M., Marzluff, J.M., and Yates, R.E. 2001. Effects of anthropogenic food sources on movements, survivorship, and sociality of common ravens in the Arctic. Condor 103:399-404.

Robertson, E. and Barry, P.J. 1985. The water and energy balances of Perch Lake (1969–1980). Atmosphere-Ocean 23:238-253.

Ruggiero, L.F., Hayward, G.D., and Squires, J.R. 1994. Viability analysis in biological evaluations: concepts of population viability analysis, biological population, and ecological scale. Conservation Biology 8:364-372.

Rusek, A. and Marshall, V.G. 2000. Impacts of Airborne Pollutants on Soil Fauna. Annual Review of Ecology and Systematics 31:395-423.

Schieck, J. and Song, S.J. 2006. Changes in bird communities throughout succession following fire and harvest in boreal forests of western North America: literature review and meta-analyses. Canadian Journal of Forest Research 36:1299-1318.

Schmiegelow, F.K.A. and Monkkonen, M. 2002. Habitat loss and fragmentation in dynamic landscapes: avian perspectives from the boreal forest. Ecological Applications 12:375 389.

Schmiegelow, F.K.A., Machtans, C.S., and Hannon, S.J. 1997. Are boreal birds resilient to forest fragmentation? An experimental study of short term community responses. Ecology 78:1914-1932.

Segers, J. and Broders, H. 2014. Interspecific effects of forest fragmentation on bats. Canadian Journal of Zoology 92(8):665-673.

Sleep, D.J.H., Drever, M.C., and Szuba, K.J. 2009. Potential role of spruce budworm in range wide decline of Canada warbler. Journal of Wildlife Management 73:546 555.

Soulé, M.E., Estes, J.A., Berger, J., and Del Rio, C.M. 2003. Ecological effectiveness: Conservation goals for interactive species. Conservation Biology 17:1238-1250.

Soulé, M.E., Estes, J.A., Miller, B., and Honnold, D.L. 2005. Strongly interacting species: conservation policy, management, and ethics. BioScience 55:168-176.

St. Clair, C.C., Belisle, M., Desrochers, A., and Hannon, S. 1998. Winter responses of forest birds to habitat corridors and gaps. Conservation Ecology 2:13 [online]. http://www.consecol.org/vol2/iss2/art13/.

Steen, D.A. and J.P. Gibbs. 2004. Effects of Roads on Structure of Freshwater Turtle Populations. Conservation Biology 18: 1143-1148.

Steen, D.A. and Smith, L.L. 2006. Road surveys for turtles: consideration of possible sampling biases. Herpetological Conservation and Biology 1(1):9-15.

The Agency (The Canadian Environmental Assessment Agency). 2015. Operational Policy Statement: Assessing Cumulative Environmental Effects under the *Canadian Environmental Assessment Act, 2012*. March 2015. ISBN: 978-1-100-22263-9.

The Agency. 2014. Technical Guidance for Assessing Cumulative Environmental Effects under the *Canadian Environmental Assessment Act, 2012*. Draft December 2014. ISBN: 978-1-100-25181-3.

Toews, D.P.L., Taylor, S.A., Vallender, R., Breslford, A., Butcher, B.G., Messer, P.W., and Lovette, I.J. 2016. Plumage genes and little else distinguish the genomes of hybridizing warblers. Current Biology online. doi: http://dx.doi.org/10.1016/j.cub.2016.06.034.

Truscott, A.-M. Palmer, S.C., Soulsby, C., Westaway, S., and Hulme, P.E. 2008. Consequences of invasion by the alien plant *Mimulus guttatus* on the species composition and soil properties of riparian plant communities in Scotland. Perspectives in Plant Ecology, Evolution and Systematics 10:231-240.

Van Dyke, A. 2011. Forest Management Plan for the Ottawa Valley Forest, OMNR Pembroke District, Southern Region, Ottawa Valley Forest Inc. For the 10-year period from April 1, 2011 to March 31, 2021. Ottawa Valley Forest Inc., Pembroke, ON. 610 p.

Wagner, D.L. 2012. Moth decline in the northeastern United States. News of the Lepidopterists' Society 54:52-56.

Walther, G. 2010. Community and ecosystem responses to recent climate change. Philosophical Transactions of the Royal Society B 365(1549):2019-2024.

Walther G.R., Post, E., Convey, P., Menzel, A., Parmesan, C., Beebee, T.J.C., Fromentin, J.M., Hoegh-Guldberg, O., and Bairlein, F. 2002. Ecological responses to recent climate change. Nature 416:389-395.

Whitaker, J.O., Sparks, D.W., and Brack, V. 2006. Use of artificial roost structures by bats at the Indianapolis International Airport. Environmental Management 38:28-36.

WHO (World Health Organization). 2000. WHO air quality guidelines for Europe. 2nd edition.

With, K.A. and Crist, T.O. 1995. Critical thresholds in species responses to landscape structure. Ecology 76:2446-2459.

Wright, D.G. and Hopky, G.E. 1998. Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters. Canadian Technical Report of Fisheries and Aquatic Science 2107. [Accessed 8 August 2016]. iv + 34p. http://www.dfo-mpo.gc.ca/habitat/role/141/1415/14155/explosives-explosifs/index-eng.asp.

Yankovich, T.L., Killey, R.W.D., Klukas, M.H., Cornett, R.J.J., Zach, R., LaFontaine, C.R., O'Donnell, B.C., Eve, T.L., Chaput, T.J., Benz, M.L., and Haas, M.K. (AECL). The Importance of Environmental Monitoring Data in Environmental Risk Assessment: An Ecosystem Approach. In: Charlebois, P, Chair. Proceedings from the Canadian Nuclear Society 21st Annual CNS Conference; 11-14 June 2000; Toronto, ON. 20 p.

Section 5.7 – Ambient Radioactivity and Ecological Health

AMEC (AMEC Foster Wheeler). 2017. Phase 2 for the Detailed Design of the Near Surface Disposal Facility Project at Chalk River Laboratories Chalk River, Ontario. Amec Foster Wheeler Report No. 01-TZ16018-CNL. January 19, 2017.

AMEC 2016. Multidisciplinary Subsurface Investigation for the Detailed Design of the Near Surface Disposal Facility Project at Chalk River Laboratories Chalk River, Ontario Amec Foster Wheeler Report No.: TZ16018. October 31, 2016.

Anderson, P. 2009. Protection of the Environment from Ionizing Radiation in a Regulatory Context (protect): proposed numerical benchmark values. Journal of Environmental Radioactivity.

Argonne National Laboratory. 2001. User's Manual for RESRAD Version 6. ANL/EAD-4.

CNL. 2016a. Biodiversity Review for the Near Surface Disposal Facility Project. 232-509213-REPT-001.

CNL. 2012. CRL Groundwater Monitoring Program Annual Report for 2010 - 3611-01612-REPT-009.

CNL. 2013. CRL Groundwater Monitoring Program Annual Report for 2011 - CRL-509247-ASR-2011.

CNL. 2014a. CRL Groundwater Monitoring Program Annual Report for 2012 - CRL-509247-ASR-2012.

CNL. 2015b. CRL Groundwater Monitoring Program Annual Report for 2013 - CRL-509249-ASR-2013.

CNL. 2016e. CRL Groundwater Monitoring Program Annual Report for 2014 - CRL-509249-ASR-2014.

CNL. 2016b. Effluent Verification Monitoring at Chalk River Laboratories in 2015 CRL-509254-ASR-2015.

CNL. 2017a. Environmental Backgrounds, Limits and Benchmarks for Monitoring Program Design, Risk Assessment and Risk Management Decisions - Chalk River Laboratories.

CNL. 2015a. Environmental Monitoring in 2014 at Chalk River Laboratories. CRL-509243-ASR-2014 Rev 0.

CNL. 2016c. Environmental Monitoring in 2015 at Chalk River Laboratories: CRL-509243-ASR-2015.

CNL. 2014c. Environmental Risk Assessment of Chalk River Laboratories. ENVP-509220-REPT-001.

CNL ETB. 2016. Recent Perch Lake Radiological Data.

CNL. 2016g. Lifestyle Surveys: Preliminary Local Food Fractions Findings, ENVP-509200-021-000.

CNL. 2016d. Near Surface Disposal Facility Performance Assessment, Radioactive Waste Radionuclide and Hazardous Substances Inventory. 185-508600-TN-003.

CNL. 2017b. Performance Assessment for Near Surface Disposal Facility to support the Environmental Impact Statement, 232-509240-ASD-001 Revision R0.

CNL. 2015c. Radiological Contamination in the East Swamp, 2002 to 2012, 3611-121250-REPT-006.

CNL. 2014b. Subsurface Radionuclide Migration from the Chemical Pit, 3613-121250-REPT-008 Rev 0.

CNSN. 2016. Independent Environmental Monitoring Program: Chalk River Laboratories. April 06. Accessed June 10, 2016. http://www.nuclearsafety.gc.ca/eng/resources/maps-of-nuclear-facilities/iemp/ch-river.cfm

CNSC. 2013. Natural Background Radiation. Accessed June 13, 2016. http://nuclearsafety.gc.ca/eng/resources/fact-sheets/natural-background-radiation.cfm

CNSC. 2006. G-320 Assessing the Long Term Safety of Radioactive Waste Management.

CSA. 2012. Environmental Risk Assessments at Class I Nuclear Facilities and Uranium Mines and Mills. CSA N288.6-12.

CSA. 2014. Guidelines for calculating derived release limits for radioactive material in airborne and liquid effluents for normal operation of nuclear facilities, N288.1-14.

Golder. 2016b. NSDF Groundwater Flow Model.

Golder. 2016a. Subsurface Geotechnical Survey of the Proposed Near Surface Disposal Facility at Chalk River Laboratories, Chalk River, Ontario. 232-10180-ASD-001, Rev 1.

Grasty, R. L., and J. R. LaMarre. 2004. The Annual Effective Dose from Natural Sources of Ionising Radiation in Canada. Journal of Radiation Protection Dosimetry.

Health Canada. 2001. Environmental Radioactivity in Canada 1989-1996: Radiological Monitoring Annual Report.

Health Canada. 2017. Guidelines for Canadian Drinking Water Quality - Summary Table. Federal-Provincial-Territorial Committee on Drinking Water of the Federal-Provincial-Territorial Committee on Health and the Environment.

ICRP. 2008. Environmental Protection - the Concept and Use of Reference Animals and Plants, 108 Ann. ICRP 38.

ICRP. 2009. Environmental Protection: Transfer Parameters for Reference Animals and Plants.

ICRP. 1991. The 1990 Recommendations of the International Commission on Radiological Protection, . ICRP 60.

Indelman, Peter, Greg Moltyaner, and Gedeon Dagan. 1999. Determining the Hydraulic Conductivity Spatial Structure at the Twin Lake Site by Grain-Size Distribution. Ground Water (Ground Water).

Milton, G M, S J Kramer, W L Watson, and T G Kotzer. 2001. Qualitative estimates of soil disturbance in the vicinity of CANDU stations, utilizing measurements of 137Cs and 210 Pb in soil cores. Journal of Environmental Radioactivity, Ed. 55. 195-205.

NCRP. 1987. Exposure of the Population in the United States and Canada from Natural Background Radiation, Recommendations to the National Council on Radiation Protection and Measurement, NCRP Report No. 94.

NWMO. 2011. OPGs Deep Geological Repository Project for Low and Intermediate Level Waste: Preliminary Safety Report. DOE/ID-10978, Rev 2.

Ontario Ministry of Natural Resources. 2004. Lakes and Rivers Improvement Act Technical Guidelines.

OPG. 2013. 2012 Results of Radiological Environmental Monitoring Programs, N-REP-03481-10011-R000.

UNSCEAR. 1993. Sources and Effects of Ionizing Radiation, UNSCEAR 1993 Report to the General Assembly with Scientific Annexes.

US DOE. 1997. 11th International Intercomparison of Environmental Dosimeters.

Section 5.8 – Human Health

AECL (Atomic Energy of Canada Limited). 2011. Derived Release Limits (DRLs) for AECL's Chalk River Laboratories. CRL-509200-RRD-001. Revision 1. May 2011.

Argonne National Laboratory. 2001. User’s Manual for RESRAD Version 6, ANL/EAD-4, Argonne National Laboratory, Argonne, Ill, 2001 July.

CNL. 2017. Performance Assessment for Near Surface Disposal Facility to support the Environmental Impact Statement, 232-509240-ASD-001 Revision R0.

CNL (Canadian Nuclear Laboratories). 2016a. Environmental Monitoring in 2015 at Chalk River Laboratories. CRL-509243-ASR-2015. Revision 0. June 2016.

CNL. 2016b. Lifestyle Surveys: Preliminary Local Food Fractions Findings. ENVP-509200-021-000. July 2016.

CNSC (Canadian Nuclear Safety Commission). 2017. Retrieved March 9, 2017, from Natural Background Radiation: http://nuclearsafety.gc.ca/eng/resources/fact-sheets/natural-background-radiation.cfm.

CNSC. 2006. Assessing the Long Term Safety of Radioactive Waste Management. Regulatory Guide G-320. December 2006. ISBN: 978-0-662-44692-7.

CSA (Canadian Standards Association). 2014. Guidelines for calculating derived release limits for radioactive material in airborne and liquid effluents for normal operation of nuclear facilities. N288.1-14. Available at: http://shop.csa.ca/en/canada/nuclear/n2881-14/invt/27011562014

Golder (Golder Associates Ltd.). 2016. Groundwater Flow Modelling of the Near Surface Disposal Facility. Submitted to Canadian Nuclear Laboratories Ltd. Project Number: 1547525. November 2016.

Grasty, R.L. and LaMarre, J.R. 2004. The Annual Effective Dose from Natural Sources of Ionising Radiation in Canada. Journal of Radiation Protection Dosimetry, volume 108(3).

Indelman, P., Moltyaner, G. and Dagan, G. 1999. Determining the Hydraulic Conductivity Spatial Structure at the Twin Lake Site by Grain-Size Distribution. Ground Water, volume 37(2).

OPG. 2011. Deep Geologic Repository Project for Low and Intermediate Level Waste. Preliminary Safety Report. DOE/ID-10978. Revision 2. February 2011.

Section 5.9 – Land and Resource Use

AECL (Atomic Energy of Canada Limited). 2010. Environmental Impact Statement for AECL's National Research Universal Reactor Long-Term Management Project. CRL-509200-ENA-043. Revision 2. September 2010.

Algonquins of Ontario Government of Ontario and Government of Canada. 2016. Agreement-In-Principle.

AOO (Algonquins of Ontario). 2016. 2016 – 2017 Algonquin Harvest Management Plan. http://www.tanakiwin.com/community/aooharvest/.

Audet, M. 2016. Personal Communication.

Bordon, C.E. 1952. A Uniform Site Designation Scheme for Canada. Anthropology in British Columbia 3:44–48.

Canadian Environmental Assessment Act (CEAA). 2012. SC 2012, c 19, s 52. Available at: http://canlii.ca/t/51zdg.

CNL (Canadian Nuclear Laboratories). 2016. Aboriginal Engagement Report. 232-513130-REPT-001. Revision 0. August 18, 2016.

CNSC (Canadian Nuclear Safety Commission). 2016. Generic Guidelines for the Preparation of an Environmental Impact Statement pursuant to the Canadian Environmental Assessment Act 2012. May 2016. ISBN: 978-0-660-05139-0

Conservation Ontario. 2015. Your Guide to Conservation Areas Ontario. [Accessed October 8 2016] http://ontarioconservationareas.ca/component/geocode_factory/?view=mapcb&idMap=1&Itemid=538.

County of Renfrew. 2003. County Official Plan. [Updated June 19 2003; Accessed October 20 2016] http://www.countyofrenfrew.on.ca/departments/development-and-property/planning-and-land-division/county-official-plan/.

Kerr, S.J. 2012. The Management of Bait in Ontario: A Review. Fisheries Policy Section Biodiversity Branch. Ontario Ministry of Natural Resources. Peterborough, Ontario.

Ministry of Agriculture, Food and Rural Affairs. 2016. Project Summary: Agricultural Resource Inventory (ARI) 1983.0. [Updated January 4, 2016; Accessed October 7 2016]. http://www.omafra.gov.on.ca/english/landuse/gis/ari_1983.htm

MNRF (Ministry of Natural Resources and Forestry). 2016a. Land Information Ontario, 2016. [Accessed October 1 2016] https://www.javacoeapp.lrc.gov.on.ca/geonetwork/srv/en/main.home.

MNRF. 2016b. Forest Management Planning. [Updated May 9 2016; Accessed September 24 2016]. https://www.ontario.ca/page/forest-management-planning.

MRNF. 2016c. Fisheries Management Zones. [Updated July 29 2016; Accessed September 20 2016]. https://www.ontario.ca/page/fisheries-management-zones.

MNRF. 2016d. FMZ 12. [Updated June 6 2016; Accessed October 7 2016]. https://www.ontario.ca/page/fisheries-management-zone-12-fmz-12.

MNRF. 2016e. FMZ 15. [Updated August 22 2016; Accessed October 7, 2016]. https://www.ontario.ca/page/fisheries-management-zone-15-fmz-15.

MNRF. 2016f. Zone 12. [Accessed October 8 2016]. http://files.ontario.ca/environment-and-energy/fishing/2016/2016_Fishing_FMZ_12_English.pdf.

MNRF. 2016g. 2016 Hunting Regulations Summary. [Accessed October 8 2016]. https://dr6j45jk9xcmk.cloudfront.net/documents/5006/2016-ontario-hunting-regulations-english.pdf.

MRNF. 2016h. Trapping in Ontario. [Updated August 22 2016; Accessed September 20, 2016]. https://www.ontario.ca/page/trapping-ontario.

MNRF. 2015. Find a Wildlife Management Unit Map. [Updated October 6 2015; Accessed September 20 2016]. https://www.ontario.ca/travel-and-recreation/find-wildlife-management-unit-wmu-map.

MNRF. 2014a. Estimated Resident Moose Hunting Activity and Harvest by Wildlife Management Unit (2006-2013). [Accessed October 7, 2016]. https://dr6j45jk9xcmk.cloudfront.net/documents/3602/estimated-resident-moose-hunting-activity-and.pdf.

MNRF. 2014b. Estimated Resident White-tailed Deer Hunting Activity and Harvest by Wildlife Management Unit (2008-2013). [Accessed October 7 2016]. https://dr6j45jk9xcmk.cloudfront.net/documents/3600/resident-white-tailed-deer-hunting-activity.pdf.

MNRF. 2014c. Estimated Provincial Black Bear Hunting Activity and Harvest (2003-2013). [Accessed October 7 2016] https://dr6j45jk9xcmk.cloudfront.net/documents/4201/estimated-black-bear-hunting-activity-harvest.pdf.

MNRF. 2012. Aggregate Resources. [Updated: July 29, 2016; Accessed October 20, 2016]. https://www.ontario.ca/page/aggregate-resources.

OMTC (Ontario Ministry of Tourism and Culture). 2011. Standards and Guidelines for Consultant Archaeologists. ISBN: 978-4435-2192-5.

Ottawa Valley Forest Inc. 2011a. Forest Management Plan for the Ottawa Valley Forest, 2011- 2021. Supplementary Document B – Aboriginal Background Information Report.

Ottawa Valley Forest Inc. 2011b. Forest Management Plan for the Ottawa Valley Forest, 2011- 2021.

Ottawa Valley Forest Inc. 2011c. Forest Management Plan for the Ottawa Valley Forest, 2011- 2021. Supplementary Documentation – Social and Economic Description.

Robinson. B.S. 1992. Early and Middle Archaic Period Occupation in the Gulf of Maine Region: Mortuary and Technological Patterning. In Early Holocene Occupation in Northern New England. Occasional Publications in Maine Archaeology 9.

Swayze, J.K., and Cameron C.. 2016. Stage 1, 2 & 3 Archaeological Assessments at the Near Surface Disposal Facility (NSDF) on Part of Lots 20-23 Ranges A&B Buchanan Township (Geo.) Renfrew County. Prepared for Candian Nuclear Laboratories.

Swayze, J.K., and McGhee R. 2011. The Heritage Hills Site and Early Postglacial Occupation of the Ottawa Valley. Archaeology of Easern North America.

Swayze, J.K. 2012. A Stage 2 Archaeological Assessment of Wood Pole Replacement Locations on D6 115 kV hydro corridor. PIF P039-172-2011.

Swayze, J.K. 2010. Archaeological Assessments at Chalk River Laboratories, Buchanan Township (Geo.), Renfrew County 2008. PIF P039-138-2008

Swayze, J.K. 2008. Archaeological Assessments at Chalk River Laboratories, Buchanan Township (Geo.), Renfrew County. Inventory of Known Cultural Resources, Cultural Resource Management Projects, Archaeological Predictive Model, and Master Plan. CIF P039-115-2007

The Agency (Canadian Environmental Assessment Agency). 2014. Technical Guidance: Assessing Cumulative Environmental Effects under the *Canadian Environmental Assessment Act, 2012*. Draft December 2014. ISBN: 978-1-100-25181-3.

The Agency. 1996. Reference Guide on Physical and Cultural Heritage Resources under the *Canadian Environmental Assessment Act, 2012*. April 1996. ISBN : 0-662-24599-7

Town of Laurentian Hills. 2012. Town of Laurentian Hills Zoning By-law #10-12, As Amended. Consolidated November 21, 2012. [Accessed October 25 2016].http://www.laurentianhills.ca/town-services/building-planning/official-plan-and-zoning-bylaws/.

Town of Laurentian Hills. 2010. Town of Laurentian Hills Official Plan. Approved with Modifications November 17, 2010. [Accessed on October 25 2016]. http://www.laurentianhills.ca/town-services/building-planning/official-plan-and-zoning-bylaws/.

Section 5.10 – Socio-economic Environment

AECL (Atomic Energy Canada Limited). 2013. Corporate Plan Summary 2014-2015 to 2018 – 2019: Operating Budget Summary 2014-2015, Capital Budget Summary 2014-2015). [Accessed 29 April 2016]. http://www.aecl.ca/site/media/aecl/CPS%202014-15%20EN.pdf.

Beauchamp, N. Fire Chief, Town of Deep River. Fire Services. Email to Kone N., Social Specialist, Golder Associates Ltd. 20 May 2016.

Canada.com. 2012. In Booming Petawawa, No Sign of a Postwar Slowdown. [Published 27 February 2012; accessed 6 October 2016]. http://www.canada.com/business/booming+Petawawa+sign+postwar+slowdown/6191478/story.html.

CNL (Canadian Nuclear Laboratories). 2016. Potassium Iodide Tablet Distribution. [Accessed 23 August 2016]. http://www.cnl.ca/en/home/about/emergency-preparedness/ki.aspx.

City of Pembroke. 2016. Economic Profile. [Accessed 5 October 2016]. http://www.pembroke.ca/economic-development/economic-profile/.

Corporation of the City of Pembroke. 2014. Corporation of the City of Pembroke Consolidated Financial Statements For the Year Ended December 31, 2013. [Published September 2 2014; accessed 9 May 2016]. http://www.pembroke.ca/userfiles/file/Financial%20Statements-2013.pdf.

Corporation of the Town of Laurentian Hills. 2015. 2014 Financial Report. [Published 18 March 2015; accessed 9 May 2016]. http://www.laurentianhills.ca/userfiles/file/2014%20Financial%20Report%20Laurentian%20Hills.pdf

County of Renfrew. 2016a. Town of Laurentian Hills. [Accessed 23 August 2016]. http://www.countyofrenfrew.on.ca/municipalities/town-of-laurentian-hills/.

County of Renfrew. 2016b. Paramedic Services. [Accessed 16 August 2016]. http://www.countyofrenfrew.on.ca/departments/emergency-services/paramedic-services/.

County of Renfrew. 2013. Major Employers, Expansions and Downsizing and Military Establishments. [Updated 20 December 2013; accessed 24 August 2016]. http://renfrew.edtools.ca/EDTools/communityProfilePDF.inc.php?communityProfileTabs%5B0%5D=EmployMilitary&prcdcsd=3547&edtools_region=3547.

County of Renfrew. 2011. AECL Restructuring Update. [Accessed 24 August 2016]. http://www.laurentianhills.ca/userfiles/file/County%20of%20Renfrew%20-%20AECL%20Restructuring%20Presentation%282%29.PDF.

CRPD (County of Renfrew Planning Department). 2012. Official Plan – Town of Deep River. [Revised March 2012; accessed 23 August 2016]. http://www.deepriver.ca/userfiles/file/DEEP%20RIVER%20OP%20CONSOLIDATION.pdf.

Deep River. Date unknown. Accommodations. [Accessed 28 August 2016]. http://www.deepriver.ca/business-directory/Accommodations/.

Deep River. 2013. Deep River Forest Management Plan 2013-2023 Draft. [Published April 2013; accessed 28 August 2016]. http://www.deepriver.ca/userfiles/Deep%20River%20DRAFT%20FMP_public.pdf.Deep River and District Hospital. 2011a. Services. [Updated April 2011; accessed 26 August 2016]. http://www.drdh.org/services.html. Deep River and District Hospital. 2011b. Acute Inpatient Care. [Updated April 2011; accessed 26 August 2016]. http://www.drdh.org/acute.html.

Deep River and District Hospital. 2011c. 24 Hour Emergency Services. [Updated April 2011; accessed 26 August 2016]. http://www.drdh.org/emergency.html.

Dillon Consulting. 2013. Town of Deep River Fire Master Plan Final Report. [Accessed 24 May 2016]. http://www.deepriver.ca/departments/fire-department/.

Expedia. 2016. Accommodation in Pembroke. [Accessed 6 October 2016]. https://www.expedia.ca/Hotel-Search#rfrrid=TG.LP.MostPopular.SeeAllHotels&regionId=6127342.

Government of Canada. 2016a. The Canadian Nuclear Industry and its Economic Contributions. [Accessed 25 August 2016]. http://www.nrcan.gc.ca/energy/uranium-nuclear/7715.

Government of Canada. 2016b. Welcome to the Payments in Lieu of Taxes (PILT) Web Page. [Updated 20 November 2014; accessed 25 August 2016]. http://www.tpsgc-pwgsc.gc.ca/biens-property/peri-pilt/index-eng.html..

Government of Canada. 2016c. Archived - Highlights of Significant New Federal Infrastructure Investments in Petawawa. [Published 29 May 2015; accessed 25 October 2016]. http://news.gc.ca/web/article-en.do?nid=981489.

Government of Canada. 2015. News Release: Minister Fantino Announces $20 million Investment to Improve Garrison Petawawa Infrastructure, May 29, 2015. [Published 29 May 2015; accessed 19 October 2016]. http://news.gc.ca/web/article-en.do?crtr.sj1D=&crtr.mnthndVl=12&mthd=advSrch&crtr.dpt1D=6670&nid=981539&crtr.lc1D=&crtr.tp1D=&crtr.yrStrtVl=2010&crtr.kw=&crtr.dyStrtVl=20&crtr.aud1D=&crtr.mnthStrtVl=2&crtr.page=8&crtr.yrndVl=2015&crtr.dyndVl=31&_ga=1.14369079.1487989351.1433876519.

Health Canada. 2016. Guidance for Evaluating Human Health Impacts in Environmental Assessment: Noise. Healthy Environments and Consumer Safety Branch, Health Canada, Ottawa, Ontario. July 2016.

Hotel Guides. 2016. Hotels near the Canadian Forces Base Petawawa. [Accessed 29 August 2016]. http://hotelguides.com/ontario/cfb-petawawa-on-hotels.html.

Jp2g Consultants Inc. 2016. Planning Issues and Policy Options Report, Town of Deep River. [Published 26 February 2016; accessed 26 August 2016]. http://www.deepriver.ca/projects/official-plan/.

Jp2g Consultants. 2015a. Background and Scanning Report. [Published August 2015; accessed 24 August 2016]. http://www.deepriver.ca/projects/official-plan/.

Jp2g Consultants. 2015b. Visioning Report. [Published 26 October 2015; accessed 24 August 2016]. http://www.deepriver.ca/projects/official-plan/.

Laurentian Hills. 2016a. Tourism. [Accessed 24 August 2016]. http://www.laurentianhills.ca/tourism/.

Laurentian Hills. 2016b. Hotels. [Accessed 28 August 2016]. http://www.laurentianhills.ca/business/business-directory/hotels/.

Laurentian Hills. 2015. Notice: Distribution of Potassium Iodide Tablets. [Accessed 25 August 2016]. http://www.laurentianhills.ca/userfiles/file/LH-DR%20nuclear%20emerg%20prep%20KI%20TABLETS%20Primary.pdf.

MTO (Ministry of Transportation of Ontario). 2014. Ontario Road Safety Annual Report. 2013. [Accessed 2 June 2016]. http://www.mto.gov.on.ca/english/publications/ontario-road-safety-annual-report.shtml. ISSN #1710-2480.

MTO. 2010. Provincial Highways: Traffic Volumes. [Accessed 5 May 2016]. http://www.raqsb.mto.gov.on.ca/techpubs/TrafficVolumes.nsf/tvweb?OpenForm&Seq=8.

Ottawa Valley. 2016. Chalk River – Deep River. [Accessed 24 August 2016]. http://www.ottawavalley.travel/Valley_Explore/Bike/Ottawa_River_and_Algonquin_Park/Chalk_River_-_Deep_River.html.

Pembroke Regional Hospital. 2016. Welcome to Pembroke Regional Hospital. [Accessed 28 August 2016]. http://www.pembrokeregionalhospital.ca/.

Pembroke. 2016a. Welcome to the Heart of the Ottawa Valley. [Accessed 15 October 2016]. http://www.pembroke.ca/tourism/.

Pembroke. 2016b. Business and Economic Development. [Accessed 7 October 2016]. http://www.pembroke.ca/economic-development/.

Pembroke. 2016c. Fire Services. [Accessed 11 October 2016]. http://www.pembroke.ca/emergency-services/fire-services/.

Pembroke. 2016d. New Fire Hall. [Accessed 11 October 2016]. http://www.pembroke.ca/emergency-services/fire-services/new-fire-hall/.

Petawawa. 2016a. Things to do. [Accessed 15 October 2016]. http://www.petawawa.ca/things-to-do/.

Petawawa. 2016b. Commercial Business Development. [Accessed 7 October 2016]. http://www.petawawa.ca/business/economic-development/commercial-business-development.

Petawawa. 2016c. Fire Department.[Accessed 11 October 2016]. http://www.petawawa.ca/residents/fire-department/.

Petawawa Morale and Welfare Services. 2016-2017. Garrison Petawawa Information Guide, 2016-2017. Available at: https://www.cafconnection.ca/getmedia/ccde3dea-d98a-4bdd-96a0-1df600fec007/gig.aspx?ext=.pdf. Accessed March 16, 2017.

Statistics Canada. 2013a. Deep River, T, Ontario (Code 3547096) (table).National Household Survey (NHS) Profile. 2011 National Household Survey. Statistics Canada Catalogue no. 99-004-XWE. Ottawa. [Released 11 September 2013; accessed 16 August 2016]. https://www12.statcan.gc.ca/nhs-enm/2011/dp-pd/prof/details/page.cfm?Lang=E&Geo1=CSD&Code1=3547096&Data=Count&SearchText=deep%20river&SearchType=Begins&SearchPR=01&A1=All&B1=All&Custom=&TABID=1.

Statistics Canada. 2013b. Laurentian Hills, T, Ontario (Code 3547090) (table).National Household Survey (NHS) Profile. 2011 National Household Survey. Statistics Canada Catalogue no. 99-004-XWE. Ottawa. [Released 11 September 2013; accessed 16 August 2016]. https://www12.statcan.gc.ca/nhs-enm/2011/dp-pd/prof/details/page.cfm?Lang=E&Geo1=CSD&Code1=3547090&Data=Count&SearchText=laurentian&SearchType=Begins&SearchPR=01&A1=All&B1=All&Custom=&TABID=1.

Statistics Canada. 2013c. Renfrew, CTY, Ontario (Code 3547) (table). National Household Survey (NHS) Profile. 2011 National Household Survey. Statistics Canada Catalogue no. 99-004-XWE. Ottawa. [Released 11 September 2013; accessed 16 August 2016]. https://www12.statcan.gc.ca/nhs-enm/2011/dp-pd/prof/details/page.cfm?Lang=E&Geo1=CD&Code1=3547&Data=Count&SearchText=renfrew&SearchType=Begins&SearchPR=01&A1=All&B1=All&Custom=&TABID=1.

Statistics Canada. 2013d. Ontario (Code 35) (table). National Household Survey (NHS) Profile. 2011 National Household Survey. Statistics Canada Catalogue no. 99-004-XWE. Ottawa. [Released 11 September 2013; accessed 26 August 2016]. https://www12.statcan.gc.ca/nhs-enm/2011/dp-pd/prof/details/page.cfm?Lang=E&Geo1=PR&Code1=35&Data=Count&SearchText=ontario&SearchType=Begins&SearchPR=01&A1=All&B1=All&Custom=&TABID=1.

Statistics Canada. 2013e. Pembroke, CA, Ontario (Code 515) *(table).* National Household Survey (NHS) Profile. 2011 Census. Statistics Canada Catalogue no. 99-004-XWE. Ottawa. [Released 26 June 2013; accessed 5 October 2016]. http://www12.statcan.gc.ca/nhs-enm/2011/dp-pd/prof/index.cfm?Lang=E.

Statistics Canada. 2013f. Petawawa, CA, Ontario (Code 516) *(table).* National Household Survey (NHS) Profile. 2011 Census. Statistics Canada Catalogue no. 99-004-XWE. Ottawa. [Released 26 June 2013; accessed 5 October 2016]. http://www12.statcan.gc.ca/nhs-enm/2011/dp-pd/prof/index.cfm?Lang=E.

Statistics Canada. 2012a. Deep River, Ontario (Code 3547096) and Canada (Code 01) (table). Census Profile. 2011 Census. Statistics Canada Catalogue no. 98-316-XWE. Ottawa. [Released 24 October 2012; accessed 16 August 2016]. http://www12.statcan.gc.ca/census-recensement/2011/dp-pd/prof/index.cfm?Lang=E.

Statistics Canada. 2012b. Laurentian Hills, Ontario (Code 3547090) and Canada (Code 01) *(table).* Census Profile*.* 2011 Census. Statistics Canada Catalogue no. 98-316-XWE. Ottawa. [Released 24 October 2012; accessed 16 August 2016]. https://www12.statcan.gc.ca/census-recensement/2011/dp-pd/prof/details/page.cfm?Lang=E&Geo1=CSD&Code1=3547090&Geo2=PR&Code2=01&Data=Count&SearchText=laurentian%20hills&SearchType=Begins&SearchPR=01&B1=All&Custom=&TABID=1.

Statistics Canada. 2012c. Ontario (Code 35) and Canada (Code 01) *(table).* Census Profile*.* 2011 Census. Statistics Canada Catalogue no. 98-316-XWE. Ottawa. [Released 24 October 2012; accessed 16 August 2016]. https://www12.statcan.gc.ca/census-recensement/2011/dp-pd/prof/details/page.cfm?Lang=E&Geo1=PR&Code1=35&Geo2=PR&Code2=01&Data=Count&SearchText=ontario&SearchType=Begins&SearchPR=01&B1=All&Custom=&TABID=1.

Statistics Canada. 2012d. NHS Profile, Petawawa, CMA, Ontario, 2011. [Released 11 September 2013; accessed 5 October 2016]. http://census2011.ca/nhs-enm/2011/dp-pd/prof/details/page.cfm?Lang=E&Geo1=CSD&Code1=3547076&Data=Count&SearchText=Petawawa&SearchType=Begins&SearchPR=01&A1=All&B1=All&Custom=&TABID=1

Statistics Canada. 2012e. NHS Profile, Pembroke, CA, Ontario, 2011. [Released 11 September 2013; accessed 5 October 2016]. https://www12.statcan.gc.ca/nhs-enm/2011/dp-pd/prof/details/page.cfm?Lang=E&Geo1=CMA&Code1=515&Data=Count&SearchText=pembroke&SearchType=Begins&SearchPR=01&A1=All&B1=All&Custom=&TABID=1

Statistics Canada. 2011a. National Household Survey Profile, Pembroke, CA, Ontario, 2011. [Released 11 September 2013; accessed 5 October 2016]. https://www12.statcan.gc.ca/nhs-enm/2011/dp-pd/prof/details/page.cfm?Lang=E&Geo1=CMA&Code1=515&Data=Count&SearchText=pembroke&SearchType=Begins&SearchPR=01&A1=All&B1=All&Custom=&TABID=1.

Statistics Canada. 2011b. National Household Survey Profile, Petawawa, CA, Ontario, 2011. [Released 11 September 2013; accessed 5 October 2016]. https://www12.statcan.gc.ca/nhs-enm/2011/dp-pd/prof/details/page.cfm?Lang=E&Geo1=CMA&Code1=516&Data=Count&SearchText=Petawawa&SearchType=Begins&SearchPR=01&A1=All&B1=All&Custom=&TABID=1.

Stencil, K, EMS Administrator at the County of Renfrew. Email to Kone N., Social Specialist, Golder Associates Ltd. 20 May 2016.

The Agency (Canadian Environmental Assessment Agency). 2014. Technical Guidance: Assessing Cumulative Environmental Effects under the *Canadian Environmental Assessment Act, 2012*. Draft December 2014. ISBN: 978-1-100-25181-3.

The Corporation of the Town of Deep River. 2015. Strategic Plan 2014 – 2018. Report # 2015-CAO – 019. [Accessed 29 April 2016]. http://www.deepriver.ca/download.php?dl=YToyOntzOjI6ImlkIjtzOjM6IjgzMSI7czozOiJrZXkiO2k6MTt9

The Corporation of the Town of Deep River. 2014. Corporation of the Town of Deep River Consolidated Financial Statements for the Year Ended December 31, 2013. [Published 9 October 2014; accessed 6 May 2016]. https://www.google.ca/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwjGwIPY-IzPAhUO32MKHWNTDHsQFggcMAA&url=http%3A%2F%2Fwww.deepriver.ca%2Fdownload.php%3Fdl%3DYToyOntzOjI6ImlkIjtzOjM6IjgzOSI7czozOiJrZXkiO2k6Mzt9&usg=AFQjCNGfEE85iZUYzsjWX3_uXQrdlGTJ9w&sig2=qyUP2xEBIpuRYt4KzhbTkQ&bvm=bv.132479545,d.dmo.

Town of Deep River. 2015. Seniors' housing needs assessment Survey Report. [Published July 2015; accessed 28 August 2016]. http://www.deepriver.ca/projects/housing-advisory-committee/seniors-housing-survey-report-available-for-download-6278.html.

Town of Petawawa. 2015. Town of Petawawa Consolidated Financial Statements For the Year Ended December 31, 2014. [Accessed 9 May 2016]. http://www.petawawa.ca/download.php?dl=YToyOntzOjI6ImlkIjtzOjI6Ijk2IjtzOjM6ImtleSI7aTozO30=.

Tunnock Consulting Ltd. 2010. Town of Laurentian hills Official Plan. [Published 17 November 2010; accessed 24 August 2016]. http://www.laurentianhills.ca/userfiles/file/Laurentian%20Hills%20OP%20-%20Final(1).pdf.

Waito, K. Fire Chief, Laurentian Hills. Fire Services. Telephone conversation with Kone N., Social Specialist, Golder Associates Ltd. 4 May 2016.

Workforce Planning Ontario. 2015. Local Labour Market Planning Report Renfrew Lanark Region. [Accessed 6 October 2016]. http://www.renfrewlanark.com/userfiles/file/LLMP%20Report%202015-2016%20EN.pdf.

Yellow Pages. 2016a. Construction and Renovation – Deep River. [Accessed 31 August 2016]. http://www.yellowpages.ca/locations/Ontario/Deep+River/80017000.html.

Yellow Pages. 2016b. Construction and Renovation – Laurentian Hills. [Accessed 31 August 2016] http://www.yellowpages.ca/locations/Ontario/Laurentian+Hills/80017000.html.

Yellow Pages. 2016c. Building Contractors in Pembroke Ontario. [Accessed 6 October 2016] http://www.yellowpages.ca/search/si/1/Building+Contractors/Pembroke+ON.

Section 6.0 – Malfunctions and Accidents

AECL. 2013. Hazard Identification Report on Waste Management Areas. WMA-508770-HZRP-002. Revision 0. April 2013.

CNL (Canadian Nuclear Laboratories). 2017. Performance Assessment for Near Surface Disposal Facility to support the Environmental Impact Statement, 232-509240-ASD-001 Revision R0.

CNL. 2016. Licence Conditions Handbook for Chalk River Laboratories. NRTEOL-LCH-01, CRL-508760-HBK-001. Revision 4. Effective December 12, 2016.

CNL. 2015. Conduct of Safety Engineering. 145-508770-PRO-001. Revision 5. April 2015.

CNSC (Canadian Nuclear Safety Commission). 2016. REGDOC-2.10.1. Nuclear Emergency Preparedness and Response. Regulatory Guide. January 2016.

CNSC. 2011. Nuclear Criticality Safety. RD-327. 2011.

CNSC. 2009. Port Granby Screening Report. August 2009.

CNSC. 2006. G-320 CNSC Regulatory Guide. Assessing the Long Term Safety of Radioactive Waste Management December 2006. ISBN: 978-0-662-44692-7

CNSC. 2004. Regulatory Policy P-290. Managing Radioactive Waste. July 2004. ISBN: 0-662-37659-5

CSA (Canadian Standards Association). 2014a. Guidelines for Calculating Derived Release Limits for Radioactive Material in Airborne and Liquid Effluents for Normal Operation of Nuclear Facilities. CSA N288.1-14. March 2014.

CSA. 2014b. Guidelines for Calculating Derived Release Limits for Radioactive Material in Airborne and Liquid Effluents for Normal Operation of Nuclear Facilities. CSA N288.1-14. March 2014.

CSA. 2012a. Environmental Risk Assessments at Class I Nuclear Facilities and Uranium Mines and Mills. N288.6-12. December 2012.

CSA. 2012b. Guidelines for Calculating the Radiological Consequence to the Public of a Release of Airborne Radioactive Material for Nuclear Reactor Accidents. N288.2-12, June 2012.

IAEA (International Atomic Energy Association). 2012. The Safety Case and Safety Assessment for the Disposal of Radioactive Waste. IAEA SSG-23. September 2012. ISBN 978–92–0–128310–8

IAEA. 2011. Disposal of Radioactive Waste. IAEA SSR-5. April 2011. ISBN 978–92–0–103010–8

IAEA. 2010. Development and Application of Level 1 Probabilistic Safety Guide. Specific Safety Guide SSG-3. April 2010. ISBN 978–92–0–114509–3

IAEA. 2000. Generic Procedures for Assessment and Response during a Radiological Emergency. IAEA-TECDOC-1162. August 2000. ISSN 1011–4289

IAEA. 1995. Treatment of External Hazards in Probabilistic Safety Assessment for Nuclear Power Plants. Safety Practice Safety Series No. 50-P-7. 1995. ISBN: 92-0-104794-0

IAEA. 1984. Site Survey for Nuclear Power Plants. IAEA Safety Series No 50-SG-S9. June 1984. ISBN 92-0-123 884-3

ICRP (International Commission on Radiological Protection). 1998. Radiation Protection Recommendations as Applied to the Disposal of Long-lived Solid Radioactive Waste. ICRP Publication 81. Annals of the ICRP 28 (4).

ISR (International Safety Research). 2017a. Criticality Safety Document. 232-203230-REPT-003. Revision 0. 2017.

ISR. 2017b. Criticality Hazard Identification. 232-203230-REPT-002. Revision 0. 2017.

ISR. 2016. Features, Events, Processes. November 2016. NSDF-503230-REPT-004.

NWMO (Nuclear Waste Management Organization). 2011a. OPG's Deep Geologic Repository Project for Low and Intermediate Level Waste. Preliminary Safety Report. DOE/ID-10978. Revision 2. February 2011.

NWMO. 2011b. OPG's Deep Geologic Repository for Low and Intermediate Level Waste. Post-closure Safety Assessment. NWMO DGR-TR-2011-25. March 2011.

OECD/NEA (Organization for Economic Cooperation and Development Nuclear Energy Agency). 1995. The Environmental and Ethical Basis of Geological Disposal of Long-Lived Radioactive Wastes: A Collective Opinion of the Radioactive Waste Management Committee of the OECD Nuclear Energy Agency. OECD/NEA, OECD Nuclear Energy Agency. Paris, France.

Port Hope Area Initiative. 2006. Port Hope Project, Environmental Assessment Study Report. LLRWMO-03710-ENA-12003. Revision D1. January 2006.

Radiation Protection Regulations. SOR/2000-203. Available at http://laws-lois.justice.gc.ca/PDF/SOR-2000-203.pdf

Seitz, R., Y. Kumano, L. Bailey, C. Markley, E. Andersson and T. Beuth. 2014. Considerations Related to Human Intrusion in the Context of Disposal of Radioactive Waste – The IAEA HIDRA Project. Waste Management Conference. Phoenix, Arizona, USA. March 2014.

US DOE (United States Department of Energy). 2011. Performance Assessment for the Idaho CERCLA Disposal Facility Landfill. 00216-SR-01320-00001 R000. March 2011.

US NRC (United States National Research Council). 2015. User's Guide for RESRAD-OFFSITE. NUREG/CR-7189. April 2015.

US NRC. 1992. Methods for External Event Screening Quantification: Risk Methods Integration and Evaluation Program (RMIEP) Methods Development. NUREG/CR-4839. July 1992

US NRC. 1991. Procedural and Submittal Guidance for the Individual Plant Examination of External Events (IPEEE) for Severe Accident Vulnerabilities. NUREG-1407. June 1991.

US NRC. 1983. A Guide to the Performance of Probabilistic Risk Assessment for Nuclear Power Plants. NUREG/CR-2300. January 1983.

Section 7.0 – Summary of Cumulative Effects

Canadian Environmental Assessment Act, 2012. SC 2012, c 19, s 52. Available at: http://canlii.ca/t/51zdg.

The Agency (Canadian Environmental Assessment Agency). 2015. Operating Policy Statement: Assessing Cumulative Environmental Effects under the *Canadian Environmental Assessment Act, 2012*. March 2015. ISBN: 978-1-100-22263-9.

The Agency. 2014. Technical Guidance: Assessing Cumulative Environmental Effects under the *Canadian Environmental Assessment Act, 2012*. Draft December 2014. ISBN: 978-1-100-25181-3.

Section 8.0 – Summary of Significance of Residual Effects

None

Section 9.0 – Effects of the Environment on the Project

AECOM (AECOM Canada Limited). 2016b. Canadian Nuclear Laboratories Near Surface Disposal Facility Design and Consulting Services: Seismic Criteria and Assessment. AECOM Project Number: 60512856

AECOM (AECOM Canada Limited). 2016c. Canadian Nuclear Laboratories Near Surface Disposal Facility Design and Consulting Services: Seismic Analysis. AECOM Project Number: 60512856

AMAP (Arctic Monitoring and Assessment Programme). 2011. Snow, Water, Ice, and Permafrost in the Arctic (SWIPA): Climate Change and the Cryosphere. Oslo, Norway.

Berger, A., Loutre, M.F. and Crucifix M. 2003. The Earth's Climate in the Next Hundred Thousand Years. Surveys in Geophysics, volume 24(2).

Canadian Environmental Assessment Act, 2012. SC 2012, c 19, s 52. Available at: http://canlii.ca/t/51zdg.

CNL (Canadian Nuclear Laboratories). 2017. Performance Assessment for Near Surface Disposal Facility to support the Environmental Impact Statement, 232-509240-ASD-001 Revision R0.

CNL. 2013a. CRL Site Characteristics, CRL-03510-SAB-001, Revision 3, 2013 January 2013.

CNSC (Canadian Nuclear Safety Commission). 2016. Generic Guidelines for the Preparation of an Environmental Impact Statement. May 2016. ISBN: 978-0-660-05139-0.

Cheng, V.Y.S., G.B. Arhonditsis, D.M.L Sills, H. Auld, M.W. Shepard, W.A Gough, and J Klaassen. 2013. Probability of Tornado Occurrence across Canada. Journal of Climate, volume 26(23).

Clark, P.U., J.D. Shakun, S.A. Marcott, A.C. Mix, M. Eby, S. Kulp, G.K. Plattner. . 2016. Consequences of twenty-first-century policy for multi-millennial climate and sea-level change. Nature Climate Change, volume 6(4).

Environment Canada 2012. Annual 2012 Summary, Climate Trends and Variability Report.

FPTCCCEA (The Federal-Provincial-Territorial Committee on Climate Change and Environmental Assessment). 2003. Incorporating Climate Change Considerations in Environmental Assessment: General Guidance for Practitioners. Prepared by the Federal-Provincial-Territorial Committee on Climate Change and Environmental Assessment. November 2003. ISBN: 0-662-35454-0.

Hallet, B. 2011. OPG's Deep Geologic Repository for Low & Intermediate Waste: Glacial Erosion Assessment. Nuclear Waste Management Organization Report. NWMO DGR-TR-2011-18

IPCC (Intergovernmental Panel on Climate Change). 2013. Summary for Policy Makers. In: Climate Change 2013: The Physical Science Basis. Contributing of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [T.F. Stocker, D. Quin, G-K Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC. 2007: Summary for Policymakers. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Mekis, E and L.A. Vincent. 2011. An overview of the second generation adjusted daily precipitation dataset for trend analysis in Canada. Atmosphere Ocean, volume 49(2).

NRCC (National Research Council Canada). 2015. National Building Code of Canada 2015. NRCC No. 53301.

NRCC. 2005. National Building Code of Canada 2005. NRCC No. 48670.

NRCan (National Resources Canada). 2014. Canada in a Changing Climate: Sector Perspectives on Impacts and Adaption. (ed.) F.J. Warren and D.S. Lemmen. ISBN: 978-1-100-24143-2.

NRCan. 2011. Climate Stabilization Targets: Emissions, Concentrations, and Impact over Decades to Millennia. National Academies Press, Washington, DC.

NRCan. 2004. Climate Change Impacts and Adaption: A Canadian Perspective. 2004. ISBN: 0-662-33123-0.

Peltier, W.R. 2011. Long-Term Climate Change. Nuclear Waste Management Organization Report NWMO DGR-TR-2011-14 R000. Peterson, T.C., X. Zhang, M Brunet-India, and J.L. Vazquez-Aguirre. 2008. Changes in North American Extremes Derived from Daily Weather Data. Journal of Geophysical Research. Atmosphere, volume 113.

Peterson, T.C., Zhang, X., Brunet-India, M., and Vazquez-Aguirre, J.L. 2008. Changes in North American Extremes Derived from Daily Weather Data. Journal of Geophysical Research. Atmosphere, v. 113.

Vincent, L.A., Wang X.L., Milewska, E.J., Wan, H., Yang, F. and Swall V. 2012. A second generation of homogenized Canadian monthly surface air temperature for climate trend analysis. Journal of Geophysical Research, volume 117(D118).

Section 10.0 – Summary of Monitoring and Follow-up Programs

None

Section 11.0 - Conclusions

None

13.0 GLOSSARY, ACRONYMS AND UNITS

13.1 Glossary

Table 13.1-1: Glossary of Terms

Term	Definition
Acute	With reference to toxicity, having a sudden onset, lasting a short time (usually within hours or days). With reference to a stimulus, severe enough to rapidly induce a response.
Acute Toxicity	Adverse effects occurring following oral or dermal administration of a single dose of a substance, or multiple doses given within 24 hours, or an inhalation exposure of 4 hours.
Aeolian	Relates to or arising from the action of the wind.
Alpha particle	Positively charged particles consisting of two protons and two neutrons that are emitted by the nuclei of radioactive (unstable) elements as they decay. Alpha particles are relatively large and can be stopped by skin or a sheet of paper. An alpha particle is a helium nucleus.
Alpha radiation	The emission of an alpha particle from the nucleus of an atom.
Ammonia	A colorless, pungent gas used to manufacture a wide variety of nitrogen-containing organic and inorganic chemicals.
Anaerobic Conditions	Anaerobic conditions refer to a lack of free oxygen within a watercourse or waterbody. During anaerobic conditions, there is little to no biologically available oxygen.
Ancillary Infrastructure	Infrastructure necessary to support the transmission of electric power from seller to purchaser given the obligations of control areas and transmitting utilities within those control areas to maintain reliable operations of the interconnected transmission system.
Anthropogenic	Coming from or having been caused by man.
Anticipated Operational Occurrences	An operational process deviating from normal operation which is expected to occur at least once during the operating lifetime of a facility but which, in view of appropriate design provisions, does not cause any significant damage to items important to safety nor lead to accident conditions.
Archaeological Resources	Any material remains of past human life or activities which are of archaeological interest.
Areas of Natural and Scientific Interest (ANSI)	An official designation by the provincial Government of Ontario in Canada applied to contiguous geographical regions within the province that have geological or ecological features which are significantly representative provincially, regionally, or locally.
As Low As Reasonably Achievable (ALARA)	An optimization tool in radiation protection used to keep individual, workplace and public dose limits as low as reasonably achievable, social and economic factors being taken into account. ALARA is not a dose limit; it is a practice that aims to keep dose levels as far as possible below regulatory limits.
Bear Management Area (BMA)	An area of Crown land licenced annually to a tourist operator for providing bear hunting services to non-resident clients. Some BMAs can completely surround private or patent land. Bear hunting services can occur on these lands provided the licenced tourist operator allocated the BMA has obtained permission of the land owner to provide bear hunting services on the property.

Table 13.1-1: Glossary of Terms

Term	Definition
Becquerels	The SI (International System) unit of radioactivity, corresponding to one disintegration per second.
Beta particle	High-energy negatively charged electrons or positively charged positrons that are ejected by radioactive (unstable) elements as they decay. A beta particle is identical in mass and charge to an electron. Beta particles are relatively small and can be stopped by a sheet of aluminum or plastic a few millimetres thick.
Beta Radiation	The emission of a beta particle from the nucleus of an atom.
Bioassays	Any procedure used to determine the nature, activity, location or retention of radionuclides in the body by direct measurement or by analysis of material excreted or otherwise removed from the body.
Brownfield	Abandoned, idled or under-used industrial and commercial facilities where expansion or redevelopment is complicated by real or perceived environmental contamination.
Catchment area	An extent or an area of land where all surface water from rain, melting snow, or ice converges to a single point at a lower elevation, usually the exit of the basin, where the waters join another body of water, such as a river, lake, reservoir, estuary, wetland, sea, or ocean.
Chelating Agents	A substance whose molecules can form several bonds to a single metal ion.
Chronic	Involving stimulus that is lingering or continues for a long time; often signifies periods from several weeks to years, depending on the reproductive life cycle of the species. Can be used to define either the exposure or the response to an exposure (effect). Chronic exposure typically induces a biological response of relatively slow progress and long continuance.
Contaminated Areas	An area where the condition or state of soil, water, or air caused by a substance release or escape results in an impairment of, or damage to, the environment, human health, safety, or property.
Corporate Social Responsibility	A business approach that contributes to sustainable development by delivering economic, social and environmental benefits for all stakeholders.
Crown Corporation	Any corporation that is established and regulated by a country's state or government.
Datum	A fixed starting point of a scale or operation.
Decommissioning	Administrative and technical actions taken to allow the removal of some or all of the regulatory controls from a facility. This does not apply to a repository or to certain nuclear facilities used for mining and milling of radioactive materials, for which closure is used.
Deep Geological Repository	A facility for disposal of radioactive waste located underground (usually several hundred metres or more below the surface) in a geological formation to provide long term isolation of radionuclides from the biosphere.
Detritus	Waste or debris of any kind.
Discharge Criteria	Legislative criteria detailing the amount of radioactive material acceptable within gas or liquid for a planned and controlled release to the environment.
Disposal Cell	Individual engineered cell as part of the engineered containment mound. The cells hold disposed radioactive waste.

Table 13.1-1: Glossary of Terms

Term	Definition
Drainage Basins	Area draining to a lake, stream, reservoir or other body of water.
Duty to Consult	In Canada, the duty to consult and accommodate with Aboriginal peoples arises when the Crown contemplates actions or decisions that may affect an Aboriginal person's Aboriginal or Treaty rights.
Dystrophic	Brown acidic water that is low in oxygen and supports little life, owing to high levels of dissolved humus.
Effective Porosity	Effective porosity is the total porosity less the fraction of the pore space occupied by shale or clay. In very clean sands, total porosity is equal to effective porosity.
Effluent	Liquid waste or sewage discharged into a river, lake or the sea.
Engineered Containment Mound	A physical structure designed to prevent the dispersion of radioactive substances consisting of a primary and secondary composite base liner system and composite final cover system, made up of both natural materials (e.g., compacted clay, granular materials) and synthetic materials (e.g., geosynthetic clay liner, geomembrane, geotextiles).
Environmental Assessment	A planning tool used to identify the possible environmental effects of a proposed project and to determine if the adverse effects can be mitigated.
Environmental Impact Statement	A document that provides a detailed review of an environmental assessment and related studies.
Environmental Management System	Refers to the management of an organization's environmental programs in a comprehensive, systematic, planned and documented manner. It includes the organizational structure, planning and resources for developing, implementing and maintaining policy for environmental protection.
Eutrophic	A lake or other body of water that is rich in nutrients and supporting a dense plant population, the decomposition of which kills animal life by depriving it of oxygen.
Evapotranspiration	The process by which water is transferred from the land to the atmosphere by evaporation from the soil and other surfaces and by transpiration from plants.
Fissile	Capable of undergoing fission by interaction with slow neutrons.
Fission	The division of a heavy nucleus into two (or, rarely, more) parts with masses of equal order of magnitude; usually accompanied by the emission of neutrons and gamma radiation.
Fugitive Dust	Small airborne particulate matter which generally comes from soil. Fugitive dust is suspended in the air by wind action and human activities.
Fulvic Acid	A highly soluble organic phenol found in humus that chelates elemental mineral nutrients.
Gamma Radiation	Gamma rays are the most energetic form of electromagnetic radiation, with a very short wavelength of less than one-tenth of a nanometer. Gamma radiation is the product of radioactive atoms.
Gamma Spectroscopy	The quantitative study of the energy spectra of gamma-ray sources, in the nuclear industry, geochemical investigation, and astrophysics. Most radioactive sources produce gamma rays, which are of various energies and intensities.

Table 13.1-1: Glossary of Terms

Term	Definition
Gamma-emitters	Radionuclides that emit gamma ray photons during radioactive decay.
Geiger Tube	It is a gaseous ionization detector and uses the Townsend avalanche phenomenon to produce an easily detectable electronic pulse from as little as a single ionising event due to a radiation particle.
Geomembrane	Is a very low permeability synthetic membrane liner or barrier used with geotechnical engineering related material to control fluid (or gas) migration in a human-made project, structure, or system.
Gneissic Rocks	A highly foliated, coarse-grained metamorphic rock consisting of light-colored layers, usually of quartz and feldspar, alternating with dark-colored layers of other minerals, usually hornblende and biotite.
Green Algae	Photosynthetic algae that contain chlorophyll and store starch in discrete chloroplasts. They are eukaryotic and most live in fresh water, ranging from unicellular flagellates to more complex multicellular forms.
Greenfield	Parkland, undeveloped open space and agricultural land, usually located near the outskirts of cities and large metropolitan areas.
Greenhouse Gases	A gas in the atmosphere that absorbs and emits radiation within the thermal infrared range. The primary greenhouse gases in the Earth's atmosphere are water vapor, carbon dioxide, methane, nitrous oxide, and ozone.
Halocarbon Refrigerants	Chemicals in which one or more carbon atoms are linked by covalent bonds with one or more halogen atoms (fluorine, chlorine, bromine or iodine) resulting in the formation of organofluorine, organochlorine, organobromine, and organoiodine compounds.
Hazardous Materials	Materials that are potentially hazardous to human health and/or the environment due to their nature and quantity and that require special handling and storage techniques.
High Level Waste	Includes used nuclear fuel and other wastes (e.g., reprocessing wastes) that have been declared as radioactive waste that generate significant heat via radioactive decay. Used nuclear fuel is associated with penetrating radiation and contains significant quantities of long-lived radionuclides.
Holocene Period	Denoting the present period (epoch) of geologic time, which began after the Pleistocene approximately 11,700 years before present.
Humic Acid	Humic acids are a principal component of humic substances, which are the major organic constituents of soil (humus), peat and coal.
Hydraulic Conductivity	Symbolically represented as K, is a property of vascular plants, soils and rocks that describes the ease with which a fluid (usually water) can move through pore spaces or fractures.
Hydrofluorocarbons	Organic compounds that contain fluorine and hydrogen atoms, are the most common type of organofluorine compounds. They are commonly used in air conditioning and as refrigerants.
Indicator Species	An organism whose presence, absence or abundance reflects a specific environmental condition. Indicator species can signal a change in the biological condition of a particular ecosystem, and thus may be used as a proxy to diagnose the health of an ecosystem.

Table 13.1-1: Glossary of Terms

Term	Definition
Infrared Radiation	A type of electromagnetic radiation, as are radio waves, ultraviolet radiation, X-rays and microwaves. Infrared light is the part of the electromagnetic spectrum that people encounter most in everyday life, although much of it goes unnoticed. It is invisible to human eyes, but people can feel it as heat.
In-situ Treatment	A method of managing or treating contaminated soils, sludges and waters "in place" in a manner that does not require the contaminated material to be physically removed or excavated from where it originates.
Intermediate Level Waste	Typically exhibits levels of penetrating radiation sufficient to require shielding during handling and interim storage and contains significant quantities of long lived radionuclides.
Ion Exchange	A usually reversible exchange of one ion with another, either on a solid surface, or within a lattice. A commonly used method for treatment of liquid waste.
Ion-exchange Resins	A resin or polymer that acts as a medium for ion exchange.
Ionizing Radiation	A form of radiation that is capable of adding or removing electrons as it passes through matter (such as air, water, or living tissue).
LC_{50}	LC50 is the lethal concentration of a toxin that is required to kill 50% of the population.
Leachate	A solution that has been in contact with soil or waste and, as a result, may contain some of the soluble or suspended constituents of the material.
Lithic Scatters	Sites where prehistoric stone artefacts are found exposed, usually on the modern ground surface, having been disturbed from their original context and 'scattered' by natural or agricultural processes.
Littoral Zones	Near shore area where sunlight penetrates all the way to the sediment and allows aquatic plants (macrophytes) to grow.
Longitudinal Dispersivity	Dispersivity is an empirical property of a porous medium that determines the characteristic dispersion of the medium by relating the components of pore velocity to the dispersion coefficient across a longitudinal gradient.
Low Level Waste	Contains material with radionuclide content above established clearance levels and exemption quantities, but generally has limited amounts of long lived activity. Low-level waste requires isolation and containment for up to a few hundred years.
Ludlum 44-9 Pancake Geiger-Mueller Detector	The Geiger-Muller pancake-type detector in the Model 44-9, made by Ludlum Measurements Inc., is arguably the most popular radiation detector used throughout the world. This detector is sensitive to alpha, beta, and gamma radiation, is enclosed within a rugged metal enclosure, and is conveniently shaped and sized for checking contamination on people and objects.
Metamorphism	The change of minerals or geologic texture (distinct arrangement of minerals) in pre-existing rocks (protoliths), without the protolith melting into liquid magma (a solid-state change). The change occurs primarily due to heat, pressure, and the introduction of chemically active fluids.
Metasedimentary	Sediment or sedimentary rock that appears to have been altered by metamorphism.
Mixed Waste	Radioactive waste that also contains hazardous substances.

Table 13.1-1: Glossary of Terms

Term	Definition
Molybdenum	The chemical element of atomic number 42, a brittle silver-gray metal of the transition series, used in some alloy steels.
Near Surface Disposal Facility	A facility for disposal of radioactive waste located at or within a few tens of metres from the earth's surface.
Nitrate	A salt or ester of nitric acid, containing the anion NO_3^- or the group $—NO_3$.
Nitrification/Denitrification	The biological oxidation of ammonia or ammonium to nitrite followed by the oxidation of the nitrite to nitrate. The transformation of ammonia to nitrite is usually the rate limiting step of nitrification. Nitrification is an important step in the nitrogen cycle in soil.
Nitrite	A salt or ester of nitrous acid, containing the anion NO_2^- or the group $—NO_2$.
Noble Gases	Any of the gaseous elements helium, neon, argon, krypton, xenon, and radon, occupying Group 0 (18) of the periodic table. They were long believed to be totally unreactive but compounds of xenon, krypton, and radon are now known.
Notice of Commencement	A notice or letter that signifies the starting point for a project and the environmental assessment for the project.
Nuclear Facility, Sites	A facility and its associated land, buildings and equipment in which radioactive materials are produced, processed, used, handled, stored or disposed of on such a scale that consideration of safety is required.
Official Plan	Describes the upper, lower or single–tier municipal council's policies on how land in their community should be used.
Perfluorocarbons	Organofluorine compounds with the formula CxFy, i.e. they contain only carbon and fluorine.
Pleistocene Period	Denoting the period (epoch) of geologic time prior to the Holocene. The Pleistocene is the geological epoch which lasted from about 2,588,000 to 11,700 years ago, spanning the world's most recent period of repeated glaciations.
Polychlorinated Biphenyls (PCBs)	Any of a class of toxic aromatic compounds, often formed as waste in industrial processes, whose molecules contain two benzene rings in which hydrogen atoms have been replaced by chlorine atoms.
Pyrophoric Materials	Materials that are often water-reactive and will ignite when they contact water or humid air. They can be handled safely in atmospheres of argon or (with a few exceptions) nitrogen. Most pyrophoric fires should be extinguished with a Class D fire extinguisher for burning metals.
Radiation Field	Represents the energy lost from the source radiator to space.
Radioactive Decay	The process by which the nucleus of an unstable atom loses energy by emitting radiation, including alpha particles, beta particles, gamma rays, and conversion electrons.
Radioactive Waste	For legal and regulatory purposes, waste that contains or is contaminated with radionuclides at concentrations or activities greater than clearance levels as established by the regulatory body. It should be recognized that this definition is purely for regulatory purposes and that material with activity concentrations equal to or less than clearance levels is radioactive from a physical viewpoint — although the associated radiological hazards are considered negligible.

Table 13.1-1: Glossary of Terms

Term	Definition
Radiocarbon Dated	Also referred to as carbon dating or carbon-14 dating, is a method for determining the age of an object containing organic material by using the properties of a radioactive isotope of carbon (C-14).
Radionuclide	A nucleus (of an atom) that possesses properties of spontaneous disintegration (radioactivity). Nuclei are distinguished by their mass and atomic number.
Reasonably Foreseeable Developments	Industrial or construction projects and developments that are approved or under approval, and are likely to commence in the reasonably foreseeable future.
Refuse Pit	Artifacts left behind when a settlement or activity area is abandoned.
Relic Shoreline	Shorelines of waterbodies that were present in past glaciation periods.
Remediation	Any measures that may be carried out to reduce the exposure from existing contamination through actions applied to the contamination itself (the source) or to the exposure pathways to humans.
Residual Effects	Environmental effects predicted to remain after the application of mitigation outlined in an environmental assessment. The predicted residual effects are considered for each Project phase.
Reverse Osmosis	Movement of a solvent out of a solution under pressure through a semipermeable membrane into pure solvent or a less concentrated solution at lower pressure. This process can be used to increase the radionuclide concentration in a solution. It can also be used to remove ions, molecules and larger particles from drinking water.
Sievert	The SI unit of absorbed radiation dose in living organisms modified by radiation type and tissue weighting factors. The sievert is the unit of dose measuring the “equivalent dose" and “effective dose". It replaces the classical radiation unit the rem. Multiples of sievert used in practice include millisievert (mSv) and microsievert (μSv).
Sorption	The interaction of an atom, molecule or particle with the surface of a solid. A general term including absorption (sorption taking place largely within the pores of a solid) and adsorption (surface sorption with a non-porous solid). The processes involved may also be divided into chemisorption (chemical bonding with the substrate) and physisorption (physical attraction, for example by weak electrostatic forces).
Stage 1 assessment	A desktop assessment to identify areas where potential archaeological resources may exist.
Stage 2 assessment	The Stage 2 component of an Archaeological Assessment begins with test pit surveys completed in areas where archaeological potential was identified during the background study and property inspection (Stage 1). The second phase of Stage 2 involves “infilling” where at each positive test pit, further excavation is completed to determine if further inspection of the area is necessary.
Stage 3 assessment	The Stage 3 component of an Archaeology Assessment is a site-specific assessment and involves controlled surface pick up of material and excavation to determine the location and number of significant test pits.

Table 13.1-1: Glossary of Terms

Term	Definition
Stage 4 assessment	Stage 4 in an Archaeological Assessment involves implementing long-term management strategies for those sites recommended for mitigation in Stage 3.
Stochastic effects	A term used to group radiation-induced health effects (such as cancer or inheritable diseases) which have a statistical risk. For these diseases, the probability of their occurrence increases proportionally to the radiation dose received: the higher the dose, the higher the probability of occurrence.
Subsurface Water	Water that flows or collects beneath the Earth's surface.
Sulphur Hexafluoride	Organic, colorless, odorless, non-flammable, extremely potent greenhouse gases, which are excellent electrical insulators.
Surface water	Surface water is water collecting on the ground or in a stream, river, lake, wetland, or ocean.
Tarpaulin	Heavy-duty waterproof cloth, originally of tarred canvas.
Thermal Stratification	Refers to a change in the temperature at different depths in the lake, due to the change in the water's density with temperature. Cold water is denser than warm water and the epilimnion (surface layer) generally consists of water that is not as dense as the water in the hypolimnion (deeper layer).
Thermoluminescent Dosimeters (TLD)	A type of radiation dosimeter. A TLD measures ionizing radiation exposure by measuring the intensity of visible light emitted from a crystal in the detector when the crystal is heated. The intensity of light emitted is dependent upon the radiation exposure.
Total Suspended Solids	Solids in water that can be trapped by a filter. TSS can include a wide variety of material, such as silt, decaying plant and animal matter, industrial wastes, and sewage. High concentrations of suspended solids can cause many problems for stream health and aquatic life.
Tritium	An isotope that occurs both naturally and as a by-product in nuclear reactors. Tritium is a radioactive isotope of hydrogen having two neutrons and one proton in its nucleus; hydrogen, by comparison, has only one proton. Tritium decays by emitting an electron (beta radiation) and has a half-life of 12.33 years.
Valued Component	Refers to environmental features that may be affected by a project and that have been identified to be of concern by the proponent, government agencies, Aboriginal peoples, or the public.
Volatile Organic Compounds	Organic compounds that easily become vapors or gases.
Waste Acceptance Criteria	Quantitative or qualitative criteria specified by the regulatory body, or specified by an operator and approved by the regulatory body, for radioactive waste to be accepted by the operator of a repository for disposal, or by the operator of a storage facility for storage.
Waste Streams	The total flow of solid waste from homes, businesses, institutions, and manufacturing plants that is recycled, burned, or disposed of in landfills, or segments thereof.

13.2 Acronyms

Table 13.2-1: List of Acronyms

Acronym	Definition
AADT	Average Annual Daily Traffic
AAQC	Ambient Air Quality Criteria
AAQO	Ambient Air Quality Objectives
AECL	Atomic Energy of Canada Limited
AECOM	AECOM Canada Ltd.
ALARA	As Low As Reasonable Achievable
AM-241	Americium-241
AMS	American Meteorological Society
ANFO	Ammonium Nitrate/Fuel Oil
ANSI	Areas of Natural and Scientific Interest
AO	Aesthetic Objective
AOO	Algonquins of Ontario
APV	Aquatic Protection Values
Ar-41	Isotope Argon-41
ARI	Agricultural Resource Inventory
ASME	American Society of Mechanical Engineers
ATRIS	Aboriginal and Treaty Rights Information System
AWQC	Ambient Water Quality Criteria
BAF	Bioaccumulation Factors
BDATEA	Best Demonstrated Available Technology that is Economically Achievable
BHA	Bait Harvesting Areas
BMA	Bear Management Area
BOD	Biological Oxygen Demand
BP	Before Present
BPIP	Building Profile Input Program
C-14	Isotope Carbon 14
C_2H_3Cl	Vinyl Chloride
CA	Census Agglomeration
CAC	Criteria Air Contaminant
CAD	Canadian Dollar
CANDU	CANada Deuterium Uranium
CCC	Criterion Continuous Concentration
CCL	Compacted Clay Liner
CCME	Canadian Council of Ministers of the Environment

Table 13.2-1: List of Acronyms

Acronym	Definition
CDWQ	Canadian Drinking Water Quality
CEAA	*Canadian Environmental Assessment Act*
CELA	Canadian Environmental Law Association
CEPA	*Canadian Environmental Protection Act*
CFB	Canadian Forces Base
CH_4	Methane
C_m	Environmental Media Concentration
CNL	Canadian Nuclear Laboratories
CNSC	Canadian Nuclear Safety Commission
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
Co-60	Isotope Coblat-60
COG	CANDU Owners Group
COPC	Contaminants of Potential Concern
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CPDP	Comprehensive Preliminary Decommissioning Plan
CRL	Chalk River Laboratories
CRM	Cultural Resource Management
CRPD	County of Renfrew Planning Department
C_s	Radionuclide Concentration in Sediment
Cs-137	Isotope Cesium-137
CSA	Canadian Standards Association
C_t	Tissue Concentration
C_w	Radionuclide Concentration in Water
CWQG	Canadian Water Quality Guidelines
CWQG-PAL	Canadian Water Quality Guidelines for the Protection of Aquatic Life
C_x	Concentration in the Food Chain Item, x, of the Bird or Mammal
DC	Dose Coefficient
DC_{ext}	External Dose Coefficient
$DC_{ext,s}$	External Dose Coefficient for Exposure in Soil
$DC_{ext,ss}$	External Dose Coefficient for Exposure on Soil Surface
DC_{int}	Internal Dose Coefficient for Aquatic or Terrestrial Organism
DCP	Dust Control Plan
D_{ext}	External Dose Rate

Table 13.2-1: List of Acronyms

Acronym	Definition
DFO	Department of Fisheries and Oceans Canada
DGR	Deep Geological Repository
D_{int}	Internal Dose Rate
DLHP	Depth of Lethal Heat Penetration
DMM	Drainage Management Manual
DOE	U.S. Department of Energy
DRL	Derived Release Limit
EA	Environmental Assessment
EC_{20}	Effective Concentration to Induce a 20% Change in Response
ECCC	Environment and Climate Change Canada
ECM	Engineered Containment Mound
ECOTOX	U.S. EPA Ecotoxicology
EER	Ecological Effects Review
EIS	Environmental Impact Statement
ELC	Ecological Land Classification
EMP	Environmental Monitoring Program
EMR	East Mattawa Road
EMS	Emergency Management System
EPA	Environmental Protection Agency
ER3	Emergency Road #3
ERA	Environmental Risk Assessment
ERDF	Environmental Restoration and Disposal Facility
ESC	Environmental Stewardship Council
ESW	East Swamp Weir
ETB	Environmental Technologies Branch
EVMP	Effluent Verification Monitoring Program
FEC	Field Effect Concentration
FMP	Forest Management Plan
FMU	Forest Management Unit
FMZ	Forest Management Zone
FRI	Forest Resource Inventory
FTE	Full Time Equivalents
GCL	Geosynthetic Clay Liner
GD	Guidance Document

Table 13.2-1: List of Acronyms

Acronym	Definition
GHG	Greenhouse Gas
GHGRP	Greenhouse Gas Reporting Program
Golder	Golder Associates Ltd.
GWMF	Geologic Waste Management Facility
GWP	Global Warming Potential
H_2S	Hydrogen Sulfide
HDPE	High-Density Polyethylene
Hg	Mercury
HIDRA	Human Intrusion in the Context of Disposal of Radioactive Waste
HLW	High-Level Waste
HQ	Hazard Quotient
HTO	Tritium Oxide
I-125	Isotope Iodine-125
I-131	Isotope Iodine-131
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
IDF	Intensity-Duration Frequency
IE	Ion Exchange
ILW	Intermediate-Level Waste
IMAC	Interim Maximum Acceptable Concentration
INPO	Institute of Nuclear Power Operations
IPCC	Intergovernmental Panel on Climate Change
ISC	Industrial Source Complex
ISO	International Organization for Standardization
IWS	Integrated Waste Strategy
I_x	Ingestion Rate of Food Item, x
K-40	Isotope Potassium-40
L&ILW	Low and Intermediate Level Waste
LANL	Los Alamos National Laboratory
LC_{50}	Lethal Concentration Required to Kill 50% of the Population
LDA	Liquid Dispersal Area
LIO	Land Information Ontario
LLW	Low-Level Waste
LSA	Local Study Area
MAC	Maximum Acceptable Concentration

Table 13.2-1: List of Acronyms

Acronym	Definition
MADEP	Massachusetts Department of Environmental Protection
MBR	Membrane Bioreactor
MISA2	Municipal/Industrial Strategy for Abatement
MLSS	Mixed Liquor Suspended Solids
MMAH	Ministry of Municipal Affairs and Housing
MMM	Marshall Macklan Monaghan Limited
MNDM	Ministry of Northern Development and Mines
MNO	Métis Nation of Ontario
MNRF	Ministry of Natural Resources and Forestry
MOECC	Ontario Ministry of the Environment and Climate Change
MOEE	Ontario Ministry of the Environment and Energy
MSC	Main Stream Culvert
MTO	Ministry of Transportation of Ontario
N_2O	Nitrous Oxide
NA	Not Applicable
NAAQS	National Ambient Air Quality Objectives
NAPS	National Air Pollution Surveillance Network
NBCCC	National Building Code of Canada
NCRP	National Council on Radiation Protection
ND	Not Detected
NEA	Nuclear Energy Agency
NGO	Non-governmental organization
NHS	National Household Survey
NO_2	Nitrogen dioxide
NO_x	Nitrogen Oxides
NPD	Nuclear Power Demonstration
NPRI	National Pollutant Release Inventory
NR	None Required
NRC	National Research Council
NRCan	Natural Resources Canada
NRU	National Research Universal
NRX	National Research Experimental
NSCA	*Nuclear Safety and Control Act*
NSDF	Near Surface Disposal Facility
NV	No Value

Table 13.2-1: List of Acronyms

Acronym	Definition
NWMO	Nuclear Waste Management Organization
O. Reg.	Government of Ontario Regulation
O_3	Ozone
OBBA	Ontario Breeding Bird Atlas
OBT	Organically-Bound Tritium
OCMP	Operational Control Monitoring Program
ODWS	Ontario Drinking Water Standard
OECD	Organization for Economic Co-operation and Development
OF_s	Fraction of Time in Soil
OF_{sed}	Fraction of Time in Sediment
OF_{seds}	Fraction of Time on Sediment Surface
OF_{ss}	Fraction of Time on Soil Surface
OF_w	Fraction of Time in Water
OF_{ws}	Fraction of Time on Water Surface
OLM	Ozone Limiting Method
OMNRF	Ontario Ministry of Natural Resources and Forestry
OMTCS	Ontario Ministry of Tourism Culture and Sport
OP	Official Plan
OPG	Ontario Power Generation
OPP	Ontario Provincial Police
OPSS	Ontario Provincial Standard Specification
OSH	Occupational Safety and Health
OTN	Ontario Trail Network
OU	Odour Unit
PAB	Pointe au Baptême
Pb	Lead
PCB	Polychlorinated Biphenyls
PCG	Potential Critical Groups
PCO	Perch Creek Outlet
PCW	Perch Creek Weir
PILT	Payments in Lieu of Taxes
PL	Perch Lake
PL2	Perch Lake Inlet #2
PLO	Perch Lake Outlet
PM_{10}	Particulate Matter Smaller than 10 Microns in Diameter

Table 13.2-1: List of Acronyms

Acronym	Definition
$PM_{2.5}$	Particulate Matter Less than 2.5 Microns in Diameter
PMP	Probable Maximum Precipitation
POPC	Parameter of Potential Concern
PPE	Personal Protective Equipment
PQRA	Preliminary Quantitative Risk Assessment
PWQMN	Provincial Water Quality Monitoring Network
PWQO	Provincial Water Quality Objective
REGDOC	Regulatory Document
RFD	Reasonably Foreseeable Developments
Rn-222	Isotope Radon-222
RO	Reverse Osmosis
ROW	Right-Of-Way
RSA	Regional Study Area
RSL	Regional Screening Levels
SARA	*Species At Risk Act*
SCS	Soil Conservation Service
SENES	SENES Consultants Limited
SF_6	Sulphur Hexafluoride
SFL	Screening Frequency Level
SFR	Spent Fuel Repository
SO_2	Sulphur Dioxide
SO_x	Sulphur Oxides
SPM	Suspended Particulate Matter
SPOC	Single Point of Contact
SRC	Safety Review Committee
SSA	Site Study Area
SSG	Specific Safety Guide
SSW	South Swamp Weir
SWH	Significant Wildlife Habitat
SWOT	Strengths-Weaknesses-Opportunities-Threats
TBD	To Be Determined
TF	Transfer Factors
The Agency	The Canadian Environmental Assessment Agency
TLD	Thermoluminescent Dosimeters
TR	Technical Record

Table 13.2-1: List of Acronyms

Acronym	Definition
TSP	Total Suspended Particles
TSS	Total Suspended Soils
U.S. EPA	United State Environmental Protection Agency
UK	United Kingdom
UNFCCC	United Nations Framework Convention on Climate Change
UNSCEAR	United Nations Scientific Committee on the Effects on Atomic Radiation
US	United States
USL	Upper Subcritical Limit
UTM	Universal Transverse Mercator
VC	Valued Component
VOC	Volatile Organic Compounds
WAC	Waste Acceptance Criteria
WIPP	Waste Isolation Pilot Plant
WL	Whiteshell Laboratories
WMA	Waste Management Areas
WMU	Wildlife Management Unit
WNS	White Nose Syndrome
WNU	World Nuclear University
WR-1	Whiteshell Reactor 1
WTC	Waste Treatment Centre
WWTF	Waste Water Treatment Facility
WWTP	Waste Water Treatment Plant

13.3 Units

Table 13.3-1: List of Units

Unit	Name
%	percent
<	less than
>	greater than
≤	less than or equal to
°	degree
°C	degrees Celsius
µ	micron
µg/L	micrograms per litre
µg/m	micrograms per metre
µg/m^3	micrograms per cubic metre
µGy	microgray
µGy/day	microgray per day
µGy/h	microgray per hour
µGy/year	microgray per year
µm	micrometre
µSv	microsievert
µSv/h	microsieverts per hour
µSv/y	microsieverts per year
am^3/s	actual cubic metre per second
Bq	becquerels
Bq/g	berquerels per gram
Bq/kg	becquerels per kilogram
Bq/L	becquerel per litre
Bq/m^2	becquerels per square metre
Bq/m^3	becquerels per cubic metre
Bq/s	becquerels per second
Bq/year	becquerels per year
BqMeV/year	becquerels-million electron volts per year
CAD	Canadian dollar
cm	centimetre
cm/s	centimetres per second
CO_2e tonnes/year	tonnes of carbon dioxide equivalent per year
dB	decibel

Table 13.3-1: List of Units

Unit	Name
F	degrees Fahrenheit
g/GJ	grams per gigajoule
g/hp-hr	grams per horse power hour
g/L	grams per litre
g/m^2	grams per square metre
g/s	grams per second
g/s-m^2	grams per square metre seconds
g/VKT	grams per vehicle kilometres travelled
GJ/m^3	gigajoules per cubic metre
h	hour
H:V	Horizontal Distance to Vertical Rise
ha	hectare (10 000 m^2)
hp	horse power
hrs/day	hours per day
k	particle size multiplier for particle size range
Kd	hydraulic conductivity
kg	kilogram
kg/day	kilogram per day
kg/GJ	Kilogram per gigajoule
kg/ha/day	Kilogram per hectare per day
kg/kg	kilogram per kilogram
kg/m^3	kilogram per cubic metre
kg/Mg	kilogram/megagram (Tonne)
km	kilometre
km/h	kilometres per hour
km^2	square kilometre
kPa	kilopascals
kV	kilovolt
kW/m^3	kilowatt per cubic metre
kWh/m^2/d	kilowatt hours per square metre per day
L	litre
L/day	litre per day
L/hp-hr	litres per horse power hour
L/kg	litre per kilogram

Table 13.3-1: List of Units

Unit	Name
lb/106scf	pounds per million standard cubic feet
lb/MMBTU	pounds per million British Thermal Units
lb/VMT	pounds per vehicle miles travelled
lbs	pounds
M	million
m	metre
m/s	metre per second
m/y	metre per year
m^2	square metre
m^3	cubic metre
m^3/d	cubic metres per day
m^3/hr	cubic metre per hour
m^3/s	cubic metre per second
m^3/truck	cubic metre per truck
m^3/yr	cubic metre per year
masl	metres above sea level
mbgs	metres below ground surface
mg	milligrams
mg/L	milligrams per litre
mL	milllitres
mm	millimetre
mm(eq)	millimetres equivalent
MMBtu/106 scf	million British thermal units per million square cubic feet
MMBTU/hr	million British thermal units per hour
mSv	millisieverts
mSv/h	millisieverts per hour
mSv/yr	mSv per year
nSv/hr	nanosievert per hour
OU/m^3	odour unit per cubic metre
OU/s	odour unit per second
ppb	parts per billion
ppm	parts per million
Sv/h	sieverts per hour
t	metric tonnes

Table 13.3-1: List of Units

Unit	Name
tonnes	tonnes (1000 kg)
tonnes CO_2/L	tonnes of carbon dioxide per litre
tonnes/day	metric tonnes per day
tonnes/m^3	metric tonnes per cubic metre
tonnes/year	metric tonnes per year
tons	tons (Imperica, US)
VKT/hr	vehicle kilometres travelled per hour
yr	year

Golder Associates Ltd.
6925 Century Avenue, Suite #100
Mississauga, Ontario, L5N 7K2
Canada
T: +1 (905) 567 4444

Golder Associates